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STO TECHNICAL REPORT **TR-SAS-090**

Cost Efficiency Implications of International Cooperation

(Implications de rentabilité de la coopération internationale)

Final Report of Task Group SAS-090.

Published April 2015

Distribution and Availability on Back Cover

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The NATO Science and Technology Organization

Science & Technology (S&T) in the NATO context is defined as the selective and rigorous generation and application of state-of-the-art, validated knowledge for defence and security purposes. S&T activities embrace scientific research, technology development, transition, application and field-testing, experimentation and a range of related scientific activities that include systems engineering, operational research and analysis, synthesis, integration and validation of knowledge derived through the scientific method.

In NATO, S&T is addressed using different business models, namely a collaborative business model where NATO provides a forum where NATO Nations and partner Nations elect to use their national resources to define, conduct and promote cooperative research and information exchange, and secondly an in-house delivery business model where S&T activities are conducted in a NATO dedicated executive body, having its own personnel, capabilities and infrastructure.

The mission of the NATO Science & Technology Organization (STO) is to help position the Nations' and NATO's S&T investments as a strategic enabler of the knowledge and technology advantage for the defence and security posture of NATO Nations and partner Nations, by conducting and promoting S&T activities that augment and leverage the capabilities and programmes of the Alliance, of the NATO Nations and the partner Nations, in support of NATO's objectives, and contributing to NATO's ability to enable and influence security and defence related capability development and threat mitigation in NATO Nations and partner Nations, in accordance with NATO policies.

The total spectrum of this collaborative effort is addressed by six Technical Panels who manage a wide range of scientific research activities, a Group specialising in modelling and simulation, plus a Committee dedicated to supporting the information management needs of the organization.

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS System Analysis and Studies Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These Panels and Group are the power-house of the collaborative model and are made up of national representatives as well as recognised world-class scientists, engineers and information specialists. In addition to providing critical technical oversight, they also provide a communication link to military users and other NATO bodies.

The scientific and technological work is carried out by Technical Teams, created under one or more of these eight bodies, for specific research activities which have a defined duration. These research activities can take a variety of forms, including Task Groups, Workshops, Symposia, Specialists' Meetings, Lecture Series and Technical Courses.

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Published April 2015

ISBN 978-92-837-0219-1

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AC	Average unit Cost
AGM	Air-to-Ground tactical Missile
AJeTS	Advanced Jet Training School
ALCA L-159	Advanced Light Combat Aircraft L-159
AMRAAM	Advanced Medium Range Air-to-Air Missile
ASRAAM	Advanced Short Range Air-to-Air Missile
AWACS	Airborne Warning And Control System
BALTDEFCO	Baltic Defence Cooperation
BVR	Beyond Visual Range
C3	Communications, Command and Control
CAP	Combat Air Patrol
DND	Canadian Department of National Defence
DOD	Department Of Defence
DOTMLPF	Doctrine, Organization, Training, Materiel, Leadership, Personnel and Facilities
DOTMLPFI	Doctrine, Organization, Training, Materiel, Leadership, Personnel, Facilities and Interoperability
DRDC CORA	Defence Research and Development Canada Centre for Operational Research and Analysis
EDA	European Defence Agency
EPAF	European Participating Air Force
EU	European Union
FFI	Forsvarets forskningsinstitutt (Norwegian Defence Research Establistment)
HAW	Heavy Airlift Wing
ILO	International Labour Organization
JPO	US F-35 Joint Program Office
LS	Learning Slope
MATC	Czech Republic-led Multinational Aviation Training Centre
MNFP	Multinational Fighter Program
MOU	Memorandum Of Understanding
NAC	North Atlantic Council
NASA	National Aeronautic and Space Administration
NATO	North Atlantic Treaty Organization
NETMA	NATO Eurofighter and Tornado Management Agency
NF	NATO Fighter
NFTC	NATO Flying Training in Canada
NORDEFCO	The Norwegian, Swedish, Danish, Icelandic and Finnish Defence Cooperation
NRF	NATO Reaction Force
PD	Procurement Directive (EU Defence Procurement Directive)

QRA	NATO Quick Reaction Alert
R&D	Research and Development
ROM	Rough Order of Magnitude
RRF	Rapid Response Force
SAC	NATO Strategic Airlift Capability
SAS	System Analysis and Studies Panel
SCM	Canadian Strategic Cost Model
SIPRI	Stockholm International Peace Research Institute
TC	Transaction Cost
TTCP	The Technical Cooperation Panel
UC	Unit Cost
UK	United Kingdom of Great Britain and Northern Ireland
US	United States of America
USD	United States Dollar
YFR	Yearly Flying Rate

Preface

The Technical Team SAS-090 was approved by the NATO Research and Technology Board in September 2010 and had its first meeting in November 2010 in Paris. The participating members have been Canada, the Czech Republic, Italy, Norway (chair) and the United Kingdom.

The objective of the study is to identify a theoretical foundation for understanding cost efficiency implications of international cooperation. Based on economic theory and case studies, a framework for identifying areas of international cooperation with the potential for economic benefit is proposed as well as estimates of potential cost savings.

The Technical Team has met six times during the period of this study, including one specialist meeting where 11 speakers from the academic world, NATO and governments presented their experiences in the field of international cooperation.

Acknowledgements

The SAS-090 Technical Team acknowledges the efforts of the following individuals: (Canada) Dr. Binyam Solomon – Defence Research and Development Canada and (Norway) Gen. (ret.) Sverre Diesen – Norwegian Defence Research Establishment. The SAS-090 Technical Team also acknowledges the efforts of all the attendees at the SAS-090 Specialists' Meeting held 24-25 May 2011.

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Cost Efficiency Implications of International Cooperation

(STO-TR-SAS-090)

Executive Summary

Stagnating defence budgets, economic austerity, and the ever rising costs of defence equipment have been putting larger and larger tolls on the defence structures of NATO members. This has recently led to a NATO-wide effort named Smart Defence. Smart Defence is NATO's response to the challenges of an increasingly complex security situation, economic austerity and an uncertain future. By pooling and sharing capabilities, setting tough priorities and coordinating efforts better internationally, NATO hopes to ease the negative effects from cost escalation and falling budgets. International defence cooperation has thus been put thoroughly on the agenda.

NATO Secretary-General Anders Fogh Rasmussen presented the Smart Defence initiative at the 2012 Chicago Summit. However, international cooperation has a long history of being investigated, tested and implemented in NATO, with what can only be described as varying degrees of success. Already in 1952 NATO leaders meeting in Lisbon had agreed on military contributions through specialization of effort. Despite this agreement, six decades later NATO has largely failed to take significant steps towards specialization.

The objective of the SAS-090 study is to develop a theoretical foundation for understanding cost efficiency implications of international cooperation and to propose a framework to identify beneficial areas of international cooperation and estimate potential savings. Based on a survey of the economic literature on cooperation, a review of lessons learned from past and present military cooperation programs and a number of case studies, the SAS-090 study proposes a framework for cooperation and for assessing the potential economic benefits. The report proposes a taxonomy for categorizing different types of cooperation efforts and their implications for the partner countries. The report also identifies a number of parameters, both economic and non-economic, that are deemed to be critical in the choice of the cooperation arrangement. A decision-support tool has been developed to assess the impact of non-economic factors on the potential success of new or existing cooperation programs.

The report presents three case studies showing that large economic gains can be achieved through cooperation. The size of the gains that each Nation can expect to see in a collaboration initiative depends on the chosen area and design of the collaboration. The main findings of the report relate to the importance of scale economies in international cooperation and how these can be captured. The extent of transaction costs incurred when cooperating can potentially outweigh the gains, implying that cooperation needs to be carefully established and managed in order to be successful. This can be achieved, for instance, by limiting the number of partners or setting up a clear lead Nation.

The taxonomy in this report structures cooperation efforts into 6 categories, depending on the military level (support, capability or service) and the cooperation type (specialization, integration). By and large, cooperation using specialization (Type-S) and cooperation on the upper military levels are found to have the largest economic potential. They also incur the potentially largest political costs, related to loss of national control and domestic industry. Most of the time there will be a range of lobbyists that raise awareness about the size and nature of these costs. This trade-off between monetary savings and political

hardship is not for this report to assess, but left to the politicians. However, one aim of this report is to serve as a counterbalance to those actors and raise awareness of the benefits of international cooperation.

In the current economic environment, Nations are increasingly facing the difficult choice of cooperating or accepting a future with less capable military forces. It is hoped that the SAS-090 recommendations can assist NATO countries in making the best decisions.

Implications de rentabilité de la coopération internationale

(STO-TR-SAS-090)

Synthèse

La stagnation des budgets de la défense, l'austérité économique et la hausse permanente des coûts du matériel de défense pèsent de plus en plus sur les structures militaires des membres de l'OTAN. Cela a récemment donné lieu à une initiative à l'échelle de l'OTAN, appelée « Défense Intelligente ». La Défense Intelligente est la réponse de l'OTAN aux problèmes posés par l'austérité économique, par un avenir incertain et par une situation sécuritaire de plus en plus complexe. En regroupant et en partageant les capacités, en établissant des priorités strictes et en coordonnant plus efficacement les efforts sur le plan international, l'OTAN espère atténuer les effets négatifs de la hausse des coûts et de la baisse des budgets. La coopération internationale en matière de défense est ainsi devenue la voie à suivre.

Le Secrétaire général de l'OTAN Anders Fogh Rasmussen, a présenté l'initiative de Défense Intelligente lors du sommet de Chicago de 2012. Cependant, la coopération internationale est depuis longtemps étudiée, testée et mise en pratique au sein de l'OTAN, avec plus ou moins de succès. Dès 1952, à Lisbonne, les dirigeants de l'OTAN s'étaient accordés sur les contributions militaires respectives, par une spécialisation des efforts. En dépit de cet accord, soixante ans plus tard, l'OTAN n'a pas beaucoup progressé en direction de la spécialisation.

L'objectif de l'étude du SAS-090 est de développer une base théorique permettant de comprendre les implications de la coopération internationale en matière de rentabilité et de proposer un cadre pour identifier les domaines intéressants en la matière et estimer les économies potentielles. A partir d'une étude de la littérature économique portant sur la coopération, d'une revue des enseignements tirés des programmes de coopération militaire et de plusieurs études de cas, l'étude du SAS-090 propose un cadre de coopération et d'évaluation des avantages économiques potentiels. Ce rapport propose une taxonomie de classement des différents types d'initiatives de coopération et de leurs implications pour les pays partenaires. Il identifie également un certain nombre de paramètres, à la fois économiques et non économiques, jugés fondamentaux dans le choix de l'arrangement de coopération. Un outil d'aide à la prise de décision a été élaboré pour évaluer l'effet des facteurs non économiques sur la réussite potentielle de programmes de coopération nouveaux ou existants.

Le rapport présente trois études de cas démontrant que des gains économiques élevés sont possibles grâce à la coopération. L'ampleur des gains pour chaque pays dépend du domaine choisi et de la forme de la collaboration. Les principaux résultats du rapport concernent l'importance des économies d'échelle dans la coopération internationale et la manière de les obtenir. Les frais de transaction dus à la coopération peuvent dépasser les gains, ce qui implique que la coopération doit être soigneusement établie et gérée pour réussir. Cela est possible, par exemple, en limitant le nombre de partenaires ou en désignant clairement un pays dirigeant.

La taxonomie de ce rapport classe les initiatives de coopération en six catégories, en fonction du niveau militaire (soutien, capacité ou service) et du type de coopération (spécialisation, intégration). De façon générale, la coopération faisant appel à la spécialisation (type S) et la coopération aux niveaux militaires supérieurs sont celles ayant le plus fort potentiel économique. Elles ont aussi potentiellement les coûts politiques les plus élevés, liés à la perte de contrôle national et de l'industrie nationale. La plupart du

temps, des groupes de pression soulignent le volume et la nature de ces coûts. Ce compromis entre économies pécuniaires et préjudice politique n'est pas le sujet du présent rapport. Il est laissé aux hommes et femmes politiques. Toutefois, l'un des objectifs de ce rapport est de faire contrepoids aux groupes de pression et d'exposer les avantages de la coopération internationale.

Dans l'environnement économique actuel, les pays sont de plus en plus confrontés à un choix difficile entre coopérer ou accepter de disposer à l'avenir de forces militaires moins bien équipées. Nous espérons que les recommandations du SAS-090 aideront les pays de l'OTAN à prendre les meilleures décisions.

Chapter 1 – INTRODUCTION

Economic austerity and the ever-rising costs of defence equipment have been putting larger and larger tolls on the defence structures of NATO members. This has been a major drive in the NATO-wide effort named Smart Defence. By pooling and sharing capabilities, setting tough priorities and coordinating efforts better internationally[1], NATO hopes to ease the negative effects of cost escalation and falling budgets. International defence cooperation has thus been put thoroughly on the agenda.

NATO leaders agreed on the Smart Defence initiative at the 2012 Chicago Summit. However, international cooperation has a long history of being investigated, tested and implemented in NATO, with what can only be described as varying degrees of success. Already in 1952, NATO leaders meeting in Lisbon had agreed on military contributions through specialization of effort [1]. Despite this agreement, six decades later NATO has largely failed to take significant steps towards specialization. This state of affairs is an indication of the difficulties inherent to the implementation of cooperation initiatives aimed at securing economic gains.

The United States (US) is the largest NATO Member Nation both in terms of defence spending and military output. In fact, the combined defence expenditures of the remaining 27 NATO Nations does not surpass that of the US.[2] The US actually accounts for around 70 percent of the total NATO defence spending, slightly more than twice as much as the rest of NATO. One would expect that this also translates into fighting capability, with the US being slightly more than twice as capable as the rest of NATO. There is however much evidence to suggest that the US is even more capable than that, most likely several times more capable than the spending might indicate [2], [3]. This apparent higher relative military capability has been attributed to a scattered European defence industrial base and national requirements, leading to costly duplication of efforts. International defence cooperation clearly could represent a way for NATO to find cost efficient solutions that ultimately ensure continued fighting power and increased overall capability.

The aim of this report is to examine the cost efficiency implications of international cooperation. More specifically, the report establishes a theoretical foundation for understanding the cost efficiency implications of international defence cooperation and presents a case study of tactical fighter jets to illustrate the theoretical principles, estimate the potential savings and derive recommendations. In addition, the report proposes a framework for determining which collaboration initiatives are most likely to lead to the largest economic benefits.

1.1 BACKGROUND

1.1.1 Duplication of Effort

Previous studies have pointed to the costly duplication of efforts in the Alliance (see [3], [7], [8], [9] and [10] for example). Figure 1-1 might serve as a good example of this duplication. This table was originally published in 1995 [10] and juxtaposes the number of types of main combat systems in Europe and the US. A recent McKinsey study corroborates the findings illustrated in Figure 1-1 [4]. The Europeans had about three times as many different combat systems to maintain as the Americans, representing a vast duplication of effort in Europe. This imbalance between the US and Europe is especially striking when one considers the disparity between American and European defence spending. The small European Nations seem to be maintaining small and inefficient defence structures.

[1] NATO Smart Defence website, http://www nato.int/cps/en/natolive/topics_84268.htm?.

[2] Factsheet on military expenditure 2011, Stockholm International Peace Research Institute (SIPRI), (http://sipri.org/research/armaments/milex/sipri-factsheet-on-military-expenditure-2011.pdf).

System	Europe	United States of America
Land Systems		
- Main battle tanks	4	1
- Armoured fight. vehicles	16	3
- 155 mm Howitzer	3	1
Air Systems		
- Fighter-strike	7	5
- Ground attack-trainer	6	1
- Attack helicopter	7	5
- Anti-ship-missiles	9	3
- Air-to-air-missiles	8	4
Sea Systems		
- Main surface combatant ships	11	2
- Diesel submarine	7	0
- Anti-submarine torpedo	9	2
- Nuclear-powered submarine	2	1
Total	**89**	**27**

Figure 1-1: Types of Main Combat Systems in Europe and the US [10].

Furthermore, defence equipment in general is to a large extent also developed and produced domestically. According to data from the European Defence Agency (EDA) in 2009, nearly 75 percent of defence equipment in Europe is bought nationally, while some 22 percent involves European collaboration.[3] The cost savings potential related to the European NATO Nations seeking together to avoid duplication and leverage the same kinds of scale economies that the US enjoys seems evident and very large. Even if duplication is costly, countries are, for various reasons, willing to bear the cost as long as they are manageable ([5], [25]). The inability of European Nations to develop complex military equipment independently is sometimes cited as an important factor driving collaboration on procurement in Europe [6].

1.1.2 Defence Specific Inflation

The well-known and well-documented phenomenon of cost increases on military systems also adds to the worries of NATO Member Nations. This trend has been found to be remarkably persistent over a range of defence equipment programs, in various countries and over a considerable period of time [11]. For some systems, such as the bomber aircraft, the yearly cost growth amounts to a staggering 10 percent above inflation. One of the main reasons for this is the ever-growing requirements for such equipment, evident in the increases in capability with respect to size, payload and range [12]. Famously, Adelman and Augustine [17] already pointed out in 1990 that if the trend continued, the entire American defence budget would in 2054 suffice only to purchase one fighter aircraft.

[3] European Defence Agency (2010) *Defence Data 2009*, (www.eda.europe.eu/docs/documents/EDA-facts_figures-2009 (19.03.2013)).

These increases in equipment costs have been closely linked to enhancements in military capability over time [14], [15], [16]. As the next generation of a military system has greater performance than the one it replaces, countries reduce their number of platforms while retaining or even increasing their fighting capability. Rising unit costs and the corresponding reduction in the number of platforms pose few problems for the large countries as long as increased performance per unit outweighs cost. However, small- and medium-sized countries face challenges when the number of platforms falls below the threshold where it is feasible to produce the capability. This number of platforms is usually referred to as the *critical mass*, and varies from system to system, as well as between countries. In effect, several NATO Nations are already facing challenges maintaining a critical mass throughout the entire capability spectrum. For the larger Nations, these problems have been almost absent, but lately even large Nations are facing challenges acquiring and maintaining their most expensive equipment, such as nuclear submarines and aircraft carriers. Smaller Nations have been facing this for years, and many now risk having to forgo basic capabilities such as fighter aircraft and main battle tanks.

1.1.3 Decreasing Defence Spending and the Financial Crisis

The world economy experienced a contraction from 2008 – 2009 in the wake of the financial crisis. This has in turn led to pressures on most NATO Nations' defence budgets [74]. Figure 1-2 illustrates the effects of this pressure, for the US and the rest of NATO, respectively. As the figure shows, the spending in NATO, except for the US, has been falling 3 years in a row from 2009 to 2012. Even though the more severe cuts have been carried out in smaller Nations, budget cuts affect the Alliance as a whole. Between 2008 and 2012, 17 European countries have cut their defence budgets by 10 percent or more in real terms.[4]

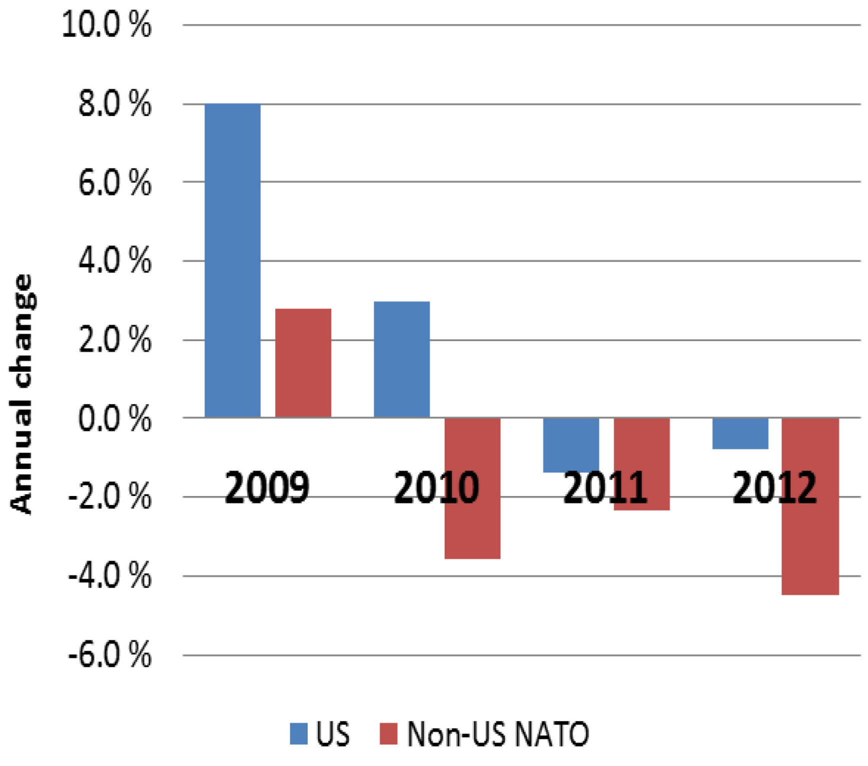


Figure 1-2: Real Change in Military Spending on Previous Year for NATO Members [19].

[4] Recent trends in military expenditure, Stockholm International Peace Research Institute (SIPRI), (http://sipri.org/reserach/armaments/milex/resultoutput/trends).

With flat or even declining budgets, and unit costs continuing to rise at a rate higher than inflation, the number of systems no longer affordable will increase for an increasing number of countries. The gap between the capabilities NATO wants and the capabilities it can actually afford will only widen in the years to come unless steps are taken to compensate for weakened finances [18]. In light of these trends, it can be argued that international cooperation is an imperative to NATO. This might be NATO's best chance to increase efficiency and reduce costs by eliminating overcapacity and duplication, and thus preparing itself for a future where weapon systems are far more expensive than today and defence budgets even smaller.

1.2 METHODOLOGY AND REPORT STRUCTURE

At the outset of the technical team's work, a methodology and plan of work was established. This methodology reflects the nature of the topic at hand. International cooperation is characterized by a striking lack of empirical data on cost savings and operational gains on one hand, and a great selection of lessons learned, cooperation concepts and opinions of right and wrong policies on the other. Of these traits, the lack of data on cost savings is the one that influenced the work of this technical team to the largest extent.

There are several reasons for the lack of available cost savings on previous cooperation efforts. Even though there are many subjective opinions on cost savings, the costing data are usually either classified, too complex to evaluate, or the before-and-after costs are not comparable. This lack of data is important since quantification of potential cost savings formed a large part of the technical team's objectives. Given this reality, in order to quantify savings and exemplify results from different types of cooperation, it was decided that the quantitative analysis would be performed as a case study. Furthermore, the case study would have to use historical cost data, but be based on a non-existing cooperation initiative. This enabled the team to establish several cooperation scenarios, where the scale and scope of the cooperation could be varied while keeping the assumptions and before-costs comparable. From this cost efficiency implications could be derived. This methodology is illustrated in Figure 1-3.

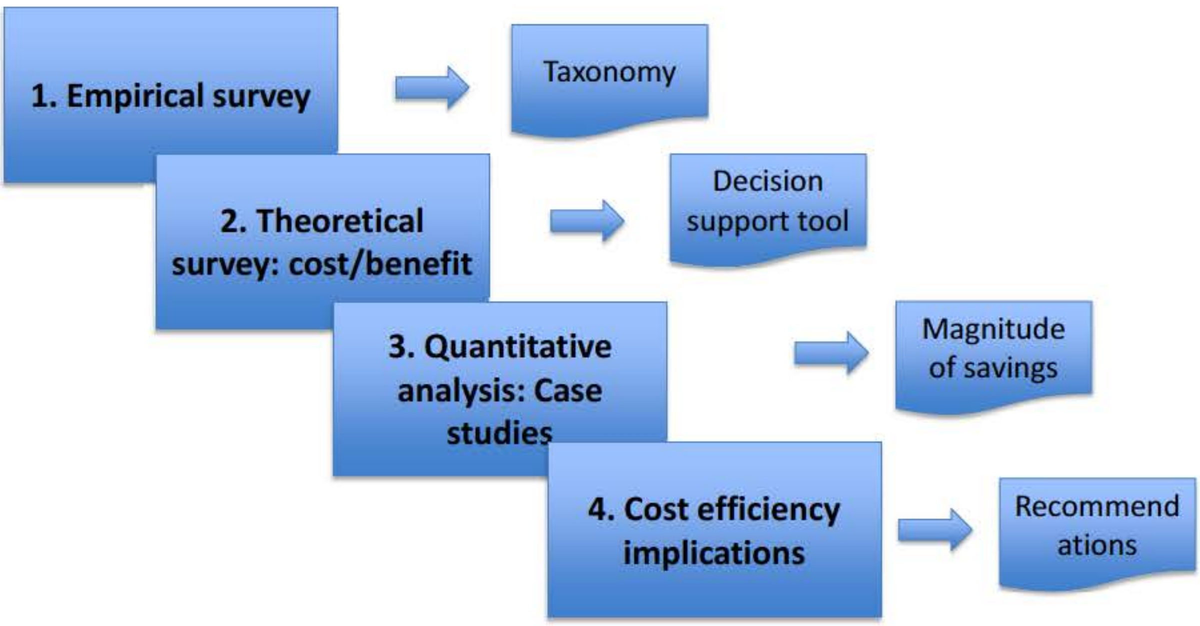


Figure 1-3: Overview of SAS-090 Methodology.

The SAS-090 technical team started with an empirical survey of military cooperation. This included setting up a Specialists' Meeting, where the team could exploit experiences and expert opinions on the subject of

military cooperation. The two-day workshop was held in Prague in the Spring of 2011 and was attended by 19 participants representing 7 different countries and 2 agencies [2]. The technical team supplemented the findings from the workshop collecting more lessons learned and conducting an extensive review of the literature on past experiences with military cooperation.

Through this empirical survey the team encountered a range of different cooperation forms, differing both in how they were organized and areas in which they operate. The first step in analyzing this myriad of cooperation forms was to establish a taxonomy for international cooperation. This taxonomy is presented in Chapter 2. The taxonomy organizes all previous cooperation arrangements in two main classes depending on whether they can be considered a predominantly integrated or specialized arrangement, and distinguishes between different military levels in a manner that allows activities on the lower levels to be viewed as inputs for the higher. This creates six main categories of international cooperation.

A central part of the methodology of the SAS-090 technical team consisted of an extensive theoretical survey of the costs and benefits of cooperation. This survey focused to a large extent on economic literature and research on cooperation, but also touched upon other disciplines. An understanding of the basic drivers of savings and costs was vital in identifying recommendations on what to cooperate on and how. This theoretical survey is presented in Chapters 3 and 4, which cover benefits and costs of international cooperation based on the workshop, literature review and lessons learned. These are divided into economic and non-economic benefits and costs.

Following the theoretical survey a quantitative analysis was conducted. This was undertaken in order to illustrate the potential savings from international cooperation. As already discussed, there are hardly any cost data available on earlier cooperation efforts. In the literature there are examples of efforts where the savings have been calculated, but these are based mostly on assumptions, as no empirical data exist for a scenario without cooperation. This makes it near impossible to ascertain the size of the cost savings. In addition, a driver behind the establishment of the technical team has been to identify potential for cost savings by cooperation that extends beyond current cooperation arrangements within NATO. For these and other reasons the case studies were not based directly on previous cooperation efforts, but rather on historical data on key parameters and simulation models. This allowed coverage of a broad range of cooperation types and levels, such as acquisition, support and operations to illustrate a realistic order of magnitude of savings in these areas. The quantitative analysis was centered around the hypothetical international cooperation on a non-existing fighter aircraft, the NATO Fighter (NF). The technological level, production costs and operation costs are based on other fighter aircrafts being developed and produced today, but do not represent a specific aircraft. The quantitative analysis is covered in Chapter 5.

Several reasons exist for choosing fighter aircraft as the foundation for the case studies. First, military aviation has a history of international cooperation, which includes lessons learned and well-documented experiences of projects of considerable size and covering a broad range of activities. Secondly, reliable cost data on fighter aircraft was available for the technical team. Even though fighter aircraft have some highly platform-specific characteristics, such as high platform costs and mobility, the actual savings calculated in the case study are closely related to the cost structure, as covered both in the theoretical background in Chapter 4 and in the case studies in Chapter 5. The particular cost structure is characterized by a high ratio of fixed to activity driven costs, which is not unique for the combat aircraft system. A report analyzing cost structures in the Norwegian Armed Forces [71] shows that the ratio of fixed to activity driven costs are about 3:1 for the Norwegian forces as a whole. Although some variation does exist amongst different systems, the ratio is remarkably constant across the services. The general results and order of magnitude savings derived from the NATO fighter case study should therefore be applicable throughout a range of different systems, including land and sea. Further, there is no reason to assume that the cost structures found in the Norwegian Armed Forces are fundamentally different from other NATO Nations, thus the findings from the cases should be valid as illustrations of potential savings in general in NATO.

The relevant data for the NATO fighter case study was collected and normalized to the extent possible. The Canadian Strategic Cost Model [20] was used to construct a basic cost structure and life cycle costs for the NATO Fighter (NF) aircraft based on the data on legacy aircraft shared by Norway and Canada (F-16 and F-18), and yield unclassified Rough Order of Magnitude (ROM) estimates. Similar calculations could be done for specific cooperation initiatives, yielding greater precision. The general observations that are derived from the case studies are applicable to other areas of defence with similar cost structures. A description of the Canadian Strategic Cost Model is provided in Annex B.

The Norwegian FLYT2 model [21], [22] that calculates aircraft availability was also used to complete the assessment of operational benefits for the case study. A description of the FLYT2 model is provided in Annex A. Chapter 6 provides a synthesis of the report by discussing implications for NATO members. Chapter 7 summarises and concludes the report.

Chapter 2 – DEFINITIONS: FORMS OF COOPERATION AND MILITARY LEVELS

International military cooperation can take many different forms, involve different degrees of integration and take place across the entire spectrum of military activities, ranging from defence Research and Development (R&D) to military operations. In parallel, both preferences and attributes vary among the countries of the Alliance, influencing which cooperation area and form is optimal. In order to analyze systematically the benefits and drawbacks of possible cooperation arrangements between NATO Nations, it is useful to categorize cooperation types.

Several terms are used in the literature to describe forms of cooperation, such as *lead Nation, framework Nation, role specialization, co-production, co-development, reciprocal trade and bi- and multi-national cooperation*. Some of these cooperative forms are defined precisely, whereas others are used in a wider sense. Typically however, previous efforts to categorize cooperative forms have been limited to cooperation in selected areas such as development and acquisition or logistics.[1] The taxonomy for categorizing international military cooperation that is presented in this report can be applied to the whole spectrum of cooperation. The purpose of such classification is to arrive at a framework for analyzing political and operational constraints as well as to identify cost efficient solutions.

Two main forms of cooperation are defined in this report: *Type-I*, where activities are conducted in an integrated manner, and *Type-S*, where activities are conducted separately with one or several Nations producing the goods and services for all. More specific definitions and examples of the two types of cooperation are presented below.

2.1 TYPE-I (INTEGRATED) COOPERATION – DOING THINGS TOGETHER

Type-I cooperation is defined as an arrangement where the production of a defence capability, asset or support function is arranged in such manner that some or all partners are cooperatively responsible for producing the defence goods in question. Prearranged agreements regulate all partners' access to the defence goods and services when required.

In Type-I cooperation integration is key to getting things done. Any activity could in principle be organized according to Type-I cooperation. Figure 2-1 exemplifies this principle if it were applied to the cooperating Nations' armies. The current situation is illustrated on the left side of Figure 2-1, where each Nation has its own army. The right side of Figure 2-1 shows a situation where the militaries have been integrated following Type-I cooperation, through the establishment of a common NATO army with national liaison elements.

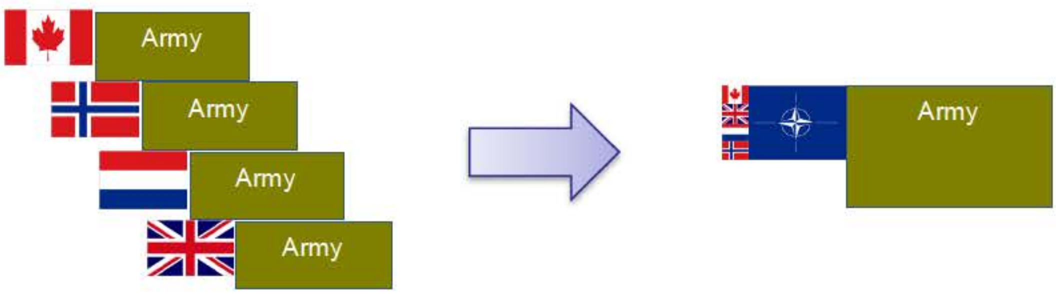


Figure 2-1: An Illustration of Type-I Cooperation.

[1] See for instance [23] and [24] for definitions of role specialization, lead Nation and multi-national cooperation and [26] for definitions of reciprocal trade, cooperative production and co-development.

2.2 TYPE-S (SPECIALIZED) COOPERATION – DOING THINGS SEPARATELY

Type-S cooperation is defined as an arrangement where the production of a defence capability, asset or support function is arranged in such manner that one or a limited number of partners are responsible for producing the defence goods and services in question. Prearranged agreements regulate all partners' access to the defence goods and services when required.

The rationale for Type-S cooperation is found in classical trade theory, where goods are produced according to the principle of lowest cost and comparative advantages, and then exchanged through market mechanisms. Production is undertaken separately, i.e. in a specialized manner, and cost savings within the Alliance for this type of cooperation are achieved by avoiding duplication of production efforts. Pre-arranged agreements must regulate all partners in the Alliance's access to the defence goods when requested. In principle the arrangement could be applied to any defence activity. Figure 2-2 exemplifies the principle for the three military services. On the left side of Figure 2-2 the current situation is depicted, where each Nation has its own army, air force and navy. On the right side of Figure 2-2 a transition has taken place to an arrangement where only one Nation is responsible for each branch of military services, and the other countries rely on their Allies for supplementing their lacking capabilities. The situation can be compared to the situation where a firm relies on sub-contractors to complete specialized work.

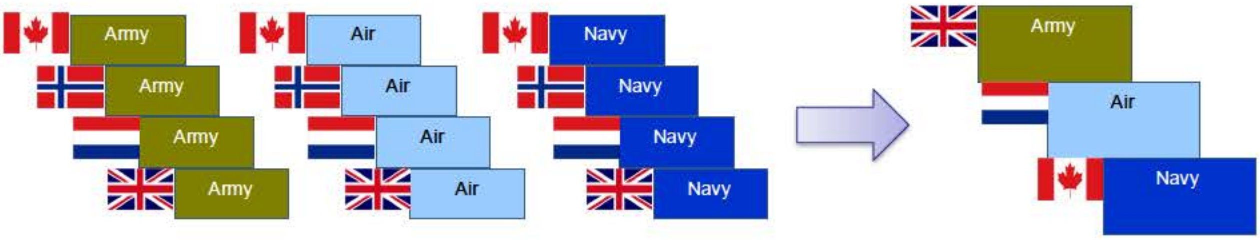


Figure 2-2: An Illustration of Type-S Cooperation.

2.2.1 The Continuum Between Type-I and Type-S Cooperation

Cooperation involving two or more Nations could take an infinite number of forms, from the two extremes that are full integration (Type-I) and full separation/specialization (Type-S), as illustrated in the previous sections, to a range of hybrid solutions in between. Depending on the military and political landscape, some forms of cooperation are more suitable than others, and implications for cost efficiency might differ.

In a Type-I cooperation, the cooperating Nations can vary in their level of integration – or how closely they are working together. An example of a highly integrated Type-I cooperation is the NATO AWACS component. Since multi-national crews operate the NATO AWACS, there is a demand for all personnel to work with common procedures, a common working language and a shared understanding of mission objectives. If, instead, the AWACS component was organized into national crews, a lower degree of integration would be required.

The rationale for Type-S cooperation is to achieve savings through specialization – or separation. In this form of cooperation, a higher degree of specialization or separation means a lower level of integration in the production of particular defence goods or services. For instance, in a Type-S cooperation, a sole Nation could produce equipment for export. In another arrangement, a lead Nation could produce equipment with the involvement of partners who define requirements and take part in the production as sub-contractors. While both examples represent Type-S cooperation, the first one represents an arrangement that is closer to the 'full' Type-S, i.e. the end of the continuum, than the second.

It should be emphasized that in the classification of forms of cooperation as Type-I and Type-S, the focus is on the process of producing defence intermediate goods[2], whether it is hardware such as an aircraft or a military capability such as the command, control and surveillance offered by NATO AWACS. Once produced, the defence intermediate goods must be integrated into the cooperating armed forces.

To summarize, the factors describing the continuum between cooperation arrangements classified as Type-I and Type-S, are integration and separation respectively. The two factors are complementary, in that an increasing degree of one equals reduction in the other. For the remainder of this report, the two main classes of cooperation are used, recognizing that there probably are hybrid cooperation arrangements that are difficult to classify mainly as one type.

2.3 CLASSIFICATION OF MILITARY LEVELS

In the discussion of the different forms of cooperation, it is useful to determine at which 'level' the cooperation is taking place. There are different ways to classify military levels of activity, and the most commonly used is according to the formation, corps, division, brigade, regiment, battalion, etc. In this report military levels are sub-divided according to practical implications for cooperation, where the lower level in general should be viewed as an input for the higher level. These levels are, starting with the highest level:

- The branch of military service level;
- The capability level; and
- The support level.

Where two or more Nations merge their entire defence structures into one common force is seen as a special case stretching above the branch level, and is not included here. Figure 2-3 illustrates the three levels at which cooperation can take place and the two main types of cooperation defined previously.

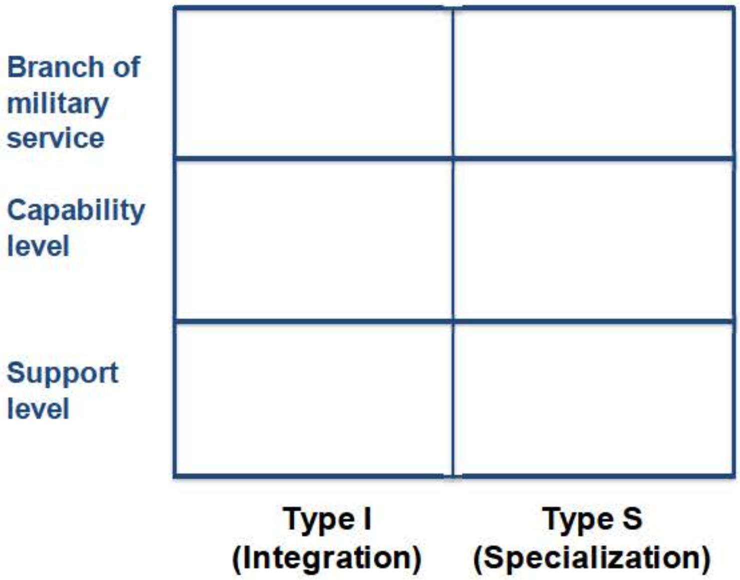


Figure 2-3: Military Levels and Types of Cooperation.

[2] An *intermediate good* is defined as a good which is not itself a final good, but is used as an input for production. It is highly useful to view certain types of defence goods as intermediate, as they require various degree of integration in order to support defence production efficiently. For instance, artillery delivered to support an infantry unit is an intermediate good. Its value to the unit comes first when artillery units are trained and integrated to the level where fire arrives with precision and on time.

Cooperation at the ‘Branch of military service’ level was used to illustrate Type-I and Type-S cooperation in Figure 2-1 and Figure 2-2. Cooperation at this level requires a high level of political trust, integration and the ability to conduct operations together (interoperability), as one Nation’s use of military force depends on the other(s). This level of cooperation could easily be perceived as seriously limiting the political freedom of action in terms of national crisis management capability. Cooperation at this level represents a situation that is far from the current reality of military cooperation for most NATO Nations.

At the ‘Capability’ level, cooperation involves the military use of systems or platforms during peacetime and in operations, either in common or in a specialized/separate manner. There are several examples of existing cooperation at this level within the Alliance, such as the NATO AWACS component. The NATO E-3A aircraft are flown by integrated multi-national crews from 16 Nations; this cooperation clearly falls into the Type-I category at the system level. The decision of New Zealand to disband its air combat fleet in 2001 has been argued to be a case of specialization or Type-S cooperation, as the Nation then relies on its ally Australia to provide the air combat capability [2][3]. Similarly, Belgium provides an air policing capability for Luxembourg, and since 2004 NATO Nations have provided the capability on a rotational basis for the Baltic States. The latter examples would fall into Type-S cooperation when seen from the viewpoint of the Baltic States, as the other countries have specialized in a capability that they are lacking. However, for the Allies providing the air policing capability, this cooperation can be seen as Type-I cooperation requiring a low level of integration, where they operate within a common NATO framework with host Nation support.

At the ‘Support’ level are activities such as training, maintenance, supply, development and production of military equipment. There are numerous examples of cooperation taking place at this level such as the shared development of new equipment, common pilot training, and shared or multi-national logistics arrangements. The co-development and later co-production of the Eurofighter Typhoon is an example of Type-I cooperation, whereas the F-35 development could be mainly classified as Type-S.

The different military levels are classified in such a way that the outputs from lower levels are inputs for the higher levels. For a system such as combat aircraft for instance, aircraft production, training of personnel and maintenance are all supporting activities that could be viewed as input for the operation of the combat aircraft at the capability level. Likewise, operational capabilities, such as combat aircraft, main battle tanks and frigates, constitute inputs to the branch of military services level.

Obviously, there are exceptions that do not fit into a discrete classification of military levels. A corps or a division, for instance, would fit somewhere between the branch and capability level. Pairs of input and output exist within a certain level, such as R&D and subsequent production of military equipment, which both fall under the support level in our classification. There are also examples of capabilities that are inputs to the support level. For instance, the capability fighter aircraft is used for training. The main characteristics of the different military levels are nevertheless useful when analyzing factors affecting cooperation.

Whereas the support level mainly could be said to consist of supporting activities, the capability level is largely operational in nature. Further, the ‘branch of military service’ could be viewed as a higher strategic level. Again, keeping in mind these are generalizations, it is easy to find examples of support activities that are operational in nature and certain capabilities that are considered to be strategic.

To further clarify the taxonomy with military levels and types of cooperation, a number of existing and historical examples of cooperation in NATO are provided in the next section.

[3] To fall into the Type-S definition there must be an arrangement that ensures that New Zealand has access to the fighter capability when requested. Furthermore, New Zealand, in parallel, has been able to redirect resources previously used on fighter jets towards other activities such as the Pacific-focused Response Force in collaboration with Australia. If this is the case the Nations have in fact been able to specialize, and not just conducted uncoordinated cuts.

2.4 EXAMPLES OF MILITARY COOPERATION WITHIN NATO

Examples of ongoing and historical military cooperation within NATO are numerous. Some are provided here to illustrate the different military levels and types of cooperation. The examples are organized according to military level, from the branch level at the top, down to the support level.

2.4.1 Branch of Military Service Level

To date, there are few cooperation initiatives at the highest military level in NATO. It has been argued that cooperation at this level could be a solution to the economic challenges facing the Alliance, particularly for clusters of small and similar Nations [25]. Figure 2-4 illustrates a theoretical example of this type of cooperation, with Type-S specialization at the branch level and integrated Type-I Headquarters with liaison elements from each participating Nation.

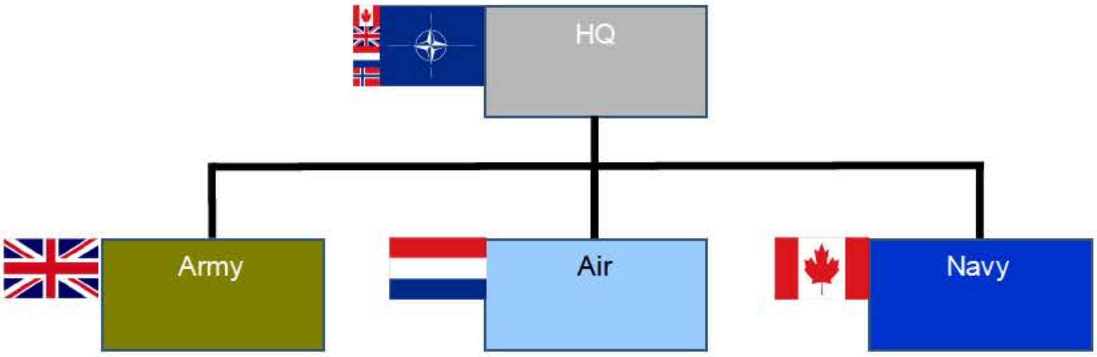


Figure 2-4: A Theoretical Example of a Force Consisting of Integrated Type-I Command and Specialized Type-S Branches of Military Services.

2.4.1.1 Dutch and Belgian Navies

The Dutch and Belgian navy cooperation stands to date as the best example of cooperation at the branch level. The two navies have a 15-year history of cooperation with regards to the operational readiness of the fleet, maintenance, training and an integrated operational command.[4] Both Nations operate the same frigates, mine hunters and are in the process of acquiring NH90-helicopters.[5] The vessels carry national flags, but large parts of the navies are integrated in a Type-I cooperation.

2.4.1.2 NATO Reaction Force

The NATO Reaction Force (NRF) is a cooperation initiative that can be classified as belonging somewhere near the top military level. NRF is a standing force comprising land, sea, air and Special Forces under Joint NATO command. Nations take turns filling the NRF with capabilities at the system level. Any decision to use force requires a consensus among all 28 members of the North Atlantic Council (NAC). The Joint Command is staffed by personnel from the participating Nations, and could be viewed as a Type-I cooperation. The contributions of the participating Nations are at the capability level and together create cooperation at the branch level. This cooperation is usually organized as a *Framework Nation* arrangement and cannot necessarily be classified as either Type-I or Type-S. However, each Nation's contribution with its own systems clearly falls into the Type-S category.

[4] The Netherlands Ministry of Defence (www.defensie.nl/english/latest/news/2012/03/08/48193676/Belgium_and_the_Netherlands_future_military_cooperation (21.03.2013)).

[5] *Ibid.*

The NATO Reaction Force is a supplementary organization for most Allies, meaning there are no coordinated efforts to specialize or achieve scale advantages in this cooperation. Contributions to the NRF are commitments to deploy forces for operations or exercises at a given readiness level, and seem to depend primarily on which units each Nation is willing to spare.

2.4.2 Capability Level

Several examples exist of cooperation at the capability level in the Alliance. For small- and medium-sized Nations, cooperation at this level comes naturally, as the alternative in several cases would be capability shortfall.

2.4.2.1 NATO Strategic Airlift Capability

The NATO Strategic Airlift Capability (SAC) agreement falls into the integrated Type-I category, as both crews and command are multi-national. Ten NATO Nations and two Partner Nations have signed the initiative to acquire, manage, support and operate three Boeing C-17 strategic transport aircraft. All three aircraft, operating from Pápa Air Base in Hungary, were delivered in 2009 and operate under the common multi-national command structure known as the Heavy Airlift Wing (HAW). It is worth noting that the development and production of the aircraft, which are activities at the support level, are undertaken single-handedly by the US, and hence not in collaboration.

2.4.2.2 Baltic Air Policing

Since 2004, NATO Nations have provided a NATO Quick Reaction Alert (QRA) for the Baltic States on a rotational basis. Belgium, Czech Republic, Denmark, France, Germany, Norway, Netherlands, Poland, Portugal, Romania, Spain, Turkey, the United Kingdom and the United States have, until 2012, taken their turn to secure the Baltic skies from Siauilai Airfield in Lithuania. Specialization in this case is achieved by eliminating the need for Baltic high performance fighter aircraft.

2.4.3 Support Level

The support level comprises activities such as training and education, maintenance, supply, engineering support, acquisition, R&D and all other activities that contribute to sustaining systems and supporting force generation. For research and development, acquisition and multi-national logistics, the examples are many and so they are treated as broad categories.

2.4.3.1 BALTDEFCO

The three Baltic Nations have joined in a Type-I cooperation with the Baltic Defence College, offering among other things, senior staff courses since 1999. The college is located in Estonia and has taught students from numerous Nations in addition to the three Baltic States.

2.4.3.2 Development

Development can be divided into *sole development* and the cooperative forms of *lead Nation development* and *co-development*.

Sole development involves the development of a military capability according mainly to the developer's requirements. If duplication of the development efforts is avoided in the Alliance through export, sole development could be viewed as a 'pure' Type-S cooperation. Reciprocal trade agreements, such as the original intention behind the AMRAAM/ASRAAM – family of weapons agreement – are examples of cooperation effort at the support level. The US-produced AMRAAM was adopted as the NATO-standard

BVR[6] missile, while German and British consortium developed and produced the complementary ASRAAM weapon system [26].[7,8]

Lead Nation usually means one Nation taking the main responsibility for the development of equipment, and therefore generally belongs to Type-S cooperation. The other participants in the cooperation could typically influence the technical requirements and participate in the main work as sub-contractors. In this type of arrangement, efforts are taken to minimize duplication. The F-35 Lightning II is a typical example of lead Nation development, where the United States bears a clear leading role in research and development.

Co-development typically falls into the Type-I category of cooperation, as the overarching development goal is usually set commonly in a consortium. However, at lower levels minimizing duplication can be achieved through sub-contracting. The term co-development has also been used to categorize projects that are eventually also produced together [26].

The Eurofighter Typhoon is typically perceived as a co-development project, where the actual workload in major part was split between the Germany, Italy, Spain and United Kingdom.

2.4.3.3 Production

Production could be sub-divided according to the same main categories as development: *sole Nation production*, *lead Nation production* and *co-production*. *Sole Nation production* represents a cooperation of Type-S if there exist agreements to ensure specialization, for instance, a reciprocal trade agreement. *Lead Nation development* can also be categorized as Type-S cooperation, whereas *co-production* can be classified as Type-I. The examples given in the previous section for corresponding development categories can also be used to illustrate the categories of production; i.e. F-35, Eurofighter and the original intention of AMRAAM/ASRAAM development. Typically, US-led development and production programs fall in the Type-S category, while European aviation programs such as A400 and Tornado fall into Type-I.

It is not always straightforward to classify a specific cooperation as Type-I or S, as real life cooperation initiatives are often complex. The co-production of the F-16 fighter aircraft stands out as a good example of this, with the US acting as the sole developer but with a European consortium consisting of the Netherlands, Belgium, Denmark and Norway demanding offsets by taking part in the aircraft production. Even though final assembly lines were set up both in Belgium and the Netherlands, with a complex flow of production parts between the cooperating Nations, the co-production could, to a large extent, be viewed as a Type-S *lead Nation production*. There were substantial transfers of technology from the US to the European partners; for example, the early European-produced aircraft had large complements of US produced parts [27].

2.4.3.4 Logistics and Support Activities

Forms of cooperation in the field of multi-national logistics are defined by NATO, and fit into the classification used previously to describe development and production. Some NATO terms include: *Logistic Lead Nation*, *Logistic Role Specialized Nation*, *Mutual Support Arrangement* and *Multi-National Integrated Logistics Unit* [23].

Logistic Lead Nation is used when one Nation assumes overall responsibility for providing or coordinating logistic support for a multi-national force within a geographical area. *Logistic Role Specialized Nation* means

[6] Beyond-Visual-Range.

[7] Flight International, 26 March 1983 (www flightglobal.com/FlightPDFArchive/1983/1983%20-%200536.PDF).

[8] Later, the partners actually failed to specialize, as ASRAAM ran into development problems with diverging specifications, and the US developed and produced the upgraded AIM-X version of Sidewinder. For further information about the AMRAAM/ASRAAM case, see, for instance [26].

that one Nation assumes responsibility for providing a particular class of supply or service for all or part of the multi-national force. A *Multi-National Integrated Logistic Unit* responds to a multi-national Commander, and the logistics support is conducted by a multi-national force. Clearly the first two fall into the Type-S category, whereas the latter belongs to Type-I.

Examples of hybrid solutions also exist in logistics, such as the *Framework Nation* arrangement, which, depending on how it is organized, could lean towards both cooperation types. In a *Framework Nation* logistics arrangement, one Nation assumes overall command and control of the forces while the other participating Nations provide liaison staff or full staff members for coordinating efforts.[9] If, on one hand, the cooperation is organized such that the Nations provide their supply and services in a specialized manner coordinated by the liaison officers, it would fall into Type-S. If, on the other hand, the *Framework Nation* arrangement is enforced by supporting Nations in a cadre-like manner, the solution could tend to be more in line with the definition of Type-I. Generally, the *Framework Nation* cooperation form is closer to Type-S, where one Nation takes the lead responsibility.

There are numerous examples of logistic support activities at the support level. One of the three case studies in this report, common pilot training, is such an example. Similar examples include the French/Belgium Advanced Jet Training School (AJeTS) for Alpha Jets and the Czech Republic-led Multinational Aviation Training Centre (MATC) for Mi-17 helicopter pilot training.

Several ambiguous cooperation initiatives exist, especially in the costly field of the maintenance and support of military aviation. For instance, the NATO Eurofighter and Tornado Management Agency (NETMA) places common maintenance and support contracts for the four participating Nations: France, Germany, Italy and the United Kingdom. Likewise, the planned sustainment system for the JSF, the so-called Autonomic Logistics Global Sustainment, is set to manage the global F-35 fleet.

Figure 2-5 summarizes the classification of known cooperative forms at the support level into the two main categories of cooperation, i.e. Type-I – Integration and Type-S – Specialization.

Function	Form	Type-I	Type-S
Development			
	Lead nation (*F-35*)		●
	Co-development (*Eurofighter*)	●	
Production			
	Reciprocal trade (*Family of Weapons*)		●
	Co-production (*Eurofighter*)	●	
Logistics			
	Role Specialization		●
	Lead nation		●
	Multinational logistics	●	

Figure 2-5: Classification of Cooperation Arrangements at the Support Level into Type-I and Type-S Categories.

[9] This definition is rewritten from [28].

2.4.4 Summary

The taxonomy presented in this section defines two main types of cooperation, Type-I (integration) and Type-S (separation/specialization), as well as the three different military levels 'branch', 'capability' and 'support'. While Type-I is characterized by doing things together, Type-S is the exact opposite and, as the name implies, is characterized by partners doing things separately. The support level sustains the operational structure, and comprise of activities such as training, maintenance, development and acquisition. The capability level also includes operational units, comprising military systems and structure elements. The branch level constitutes the more strategic level of armed forces.

It has been stressed that the taxonomy here presents main levels and categories, reflecting a real-life continuum. Among the examples of cooperation discussed so far, some clearly belong to one category or level while others are more difficult to place. Figure 2-6 sets out some of the examples of international cooperation presented in this chapter, classified according to the taxonomy.

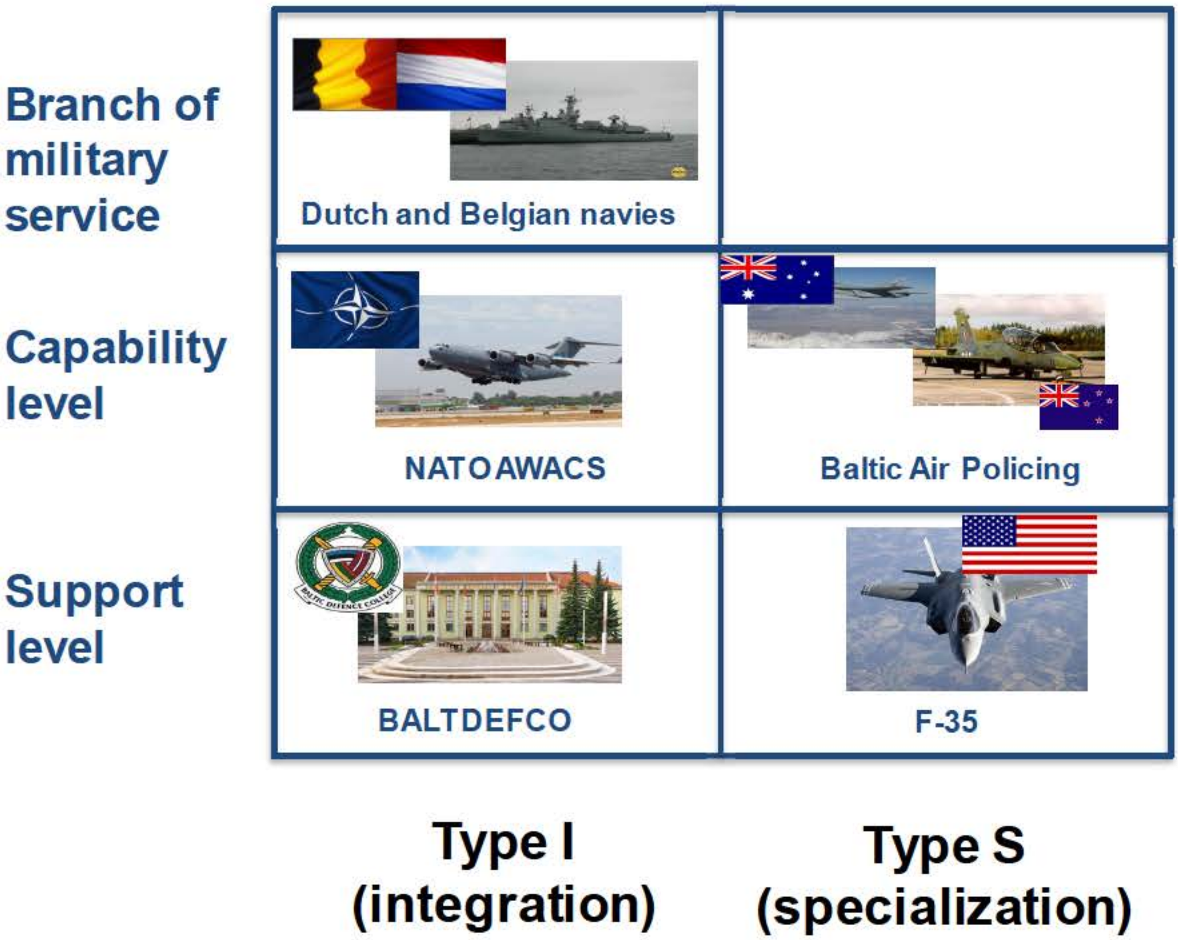


Figure 2-6: Examples of Existing Cooperation Arrangements Across Different Types and Levels.

In the next chapters, factors that are important for cooperation are investigated as well as the way in which they play out in the different types and levels of cooperation.

Chapter 3 – BENEFITS OF INTERNATIONAL COOPERATION

The benefits from cooperation are both economic and non-economic. It is important to understand the drivers behind potential benefits in order to reap the full potential of cooperation. This is especially important in areas where the benefits are mutually exclusive. For instance, it is not necessarily beneficial for Nations to invest in country-specific configurations in commonly produced platforms, once the consequences of all commonality losses are accounted for. Similarly, there is often a perception that the potential for the creation of high-technology jobs outweighs any other operational or economic benefits. In some cases this could be justified, but the long-term consequences seem to be a duplication of efforts and an inefficient defence industrial base [3], [9], [56], [57]. This chapter presents the benefits of cooperation while Chapter 4 discusses the costs and barriers of international cooperation.

The next section provides an introduction to the potential gains from collaborations, covering what causes them. Benefits can be gained in both Type-I and Type-S cooperation programs and at all military levels, although in varying degrees.

While the focus in Section 3.1 is primarily the economic benefits, the non-economic benefits are covered briefly in Section 3.2. This chapter presents relevant economic theory serving as a basis for the following analysis of the possible range and scale of the gains that can be achieved through international cooperation.

3.1 ECONOMIC GAINS FROM INTERNATIONAL COOPERATION

Economic gains from international cooperation can be divided into economies of scale and scope, learning curve effects, and international trade.

3.1.1 Economies of Scale

Economies of scale are present whenever large-scale production has a cost advantage over smaller processes [36]. More precisely, economies of scale are the prevalence of decreasing average costs as production increases.

It should be emphasized that this report's use of an extended definition of the term "production" goes beyond the typical manufacturing process in a firm. In the context used here, "production" describes the generation of all kinds of defence activities, goods and services; from force generation to logistics, acquisition and peacekeeping. Economies of scale in this context can be exemplified by the fall in the average cost of educating a soldier as the number of soldiers to be educated increases. Increasing production in this way, within the capacity of an existing production facility, thus leads to lower costs per unit produced. This is a result of the fixed costs related to the activity, the costs not affected by the activity level being evenly distributed over more units. With small-scale production or activity, these costs will constitute a large share of the total costs and the average cost of one unit produced will be high. As a Nation or a group of Nations increases activities in one area of defence, marginal costs[1] will decrease as a result of the sharing of fixed costs on more units.

The gains from scale thus depend on the co-location of production. This means that these benefits can be achieved both through Type-I and Type-S cooperation as long as the cooperating partners are willing to pool production in one location. However, the potential for economies of scale will be larger in Type-S cooperation programs because by letting all partners be cooperatively responsible for the production, as in Type-I cooperation programs, it is likely that a larger amount of each partner's fixed costs are retained, thus reducing some of the benefits of cooperation. There have been several examples of Type-I cooperation

[1] The marginal cost is the extra cost incurred by increasing activity by a small amount.

where the participants have failed to specialize entirely [37]. For instance, in the Eurofighter program where the development of every important sub-system and component involved industry from all four Nations, or development programs that duplicated production lines, including Transall C160 transport aircraft, and the fighter aircraft Jaguar, FS-X and Tornado [26].

As an illustration of this principle, consider a production process in Country 1, where the fixed cost amounts to 700 dollars, while the variable cost is 3 dollars per unit produced. As the quantity produced increases, the average unit cost will decrease as a result of the 700 dollars of fixed cost being distributed evenly over more units. The falling average unit cost curve (AC) in Figure 3-1 illustrates the cost efficiency gains from economies of scale in this example.

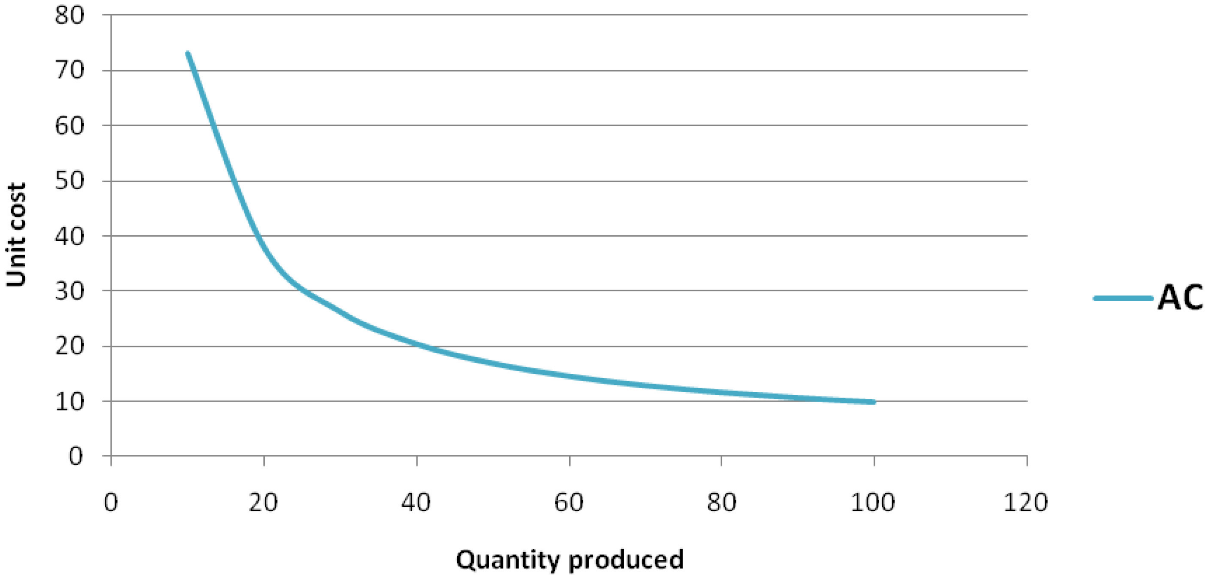


Figure 3-1: An Example of Average Unit Cost Curve (AC).

Per unit costs will decrease the more the production or the activity is increased. However, the gains will decrease in size as production grows, meaning that an increase in production from initially low-scale production gives the largest gains. This is also illustrated by the convexity of the average unit cost curve (AC) in Figure 3-1.

While cost efficiency gains can be achieved through economies of scale, the size of these gains depends highly on the cost structure of the production process. Cost efficiency gains will usually be largest in areas where the ratio of fixed cost to variable cost is large. A higher fixed cost means larger reductions in unit costs as the activity or production is increased. This can be illustrated by a steep average cost curve, implying that even a small increase in production leads to large cost reductions.

As stated above, the convex average cost curve also implies that the fall in unit costs following an increase in production will be largest in areas where initial production or activity level is low. Countries will thus see the largest fall in unit production cost from pooling production when cooperating in areas of defence where production is low scale initially, typically areas close to critical mass. Maintaining small scale activities is costly compared to the often limited effect, and cooperation in these fields will give a relatively larger unit cost reduction compared to cooperation in fields of larger initial scale.

Gains from scale can be realized in production processes at all military levels, from the support level to the branch of military service level. Historically there have been several examples of large cooperation programs

in defence R&D, for instance the fighter aircraft Eurofighter, Tornado, and F-35; transport aircraft A400, Atlantic, and Transall, and air-to-air missiles Meteor and IRIS-T. These initiatives are possibly motivated by large-scale advantages. The R&D costs are induced by the first produced unit, and thereafter will be spread on the subsequent produced units. This makes costly defence R&D programs especially good candidates for cooperation. However, the potential for scale advantages are present wherever there are large fixed costs, through the whole defence value chain. Cooperation aiming to achieve economies of scale should therefore not be limited to R&D and production.

For many Allies, defence specific inflation or unit cost escalation, as described in Chapter 1, may play a large role in determining the future ratio of fixed to variable costs in the various production processes. The consequence of rising unit costs is that fewer but more advanced platforms are being acquired, making fixed costs as a proportion of total costs in defence production rise. The increasing proportion of fixed costs creates a higher potential for gains from economies of scale through cooperation. As a result of defence specific inflation, it will become increasingly beneficial to cooperate on capital intensive production processes, such as production of most major weapon systems.

Fact Box: F-16 and the EPAF-Collaboration [55]

The agreement to collaborate in the procurement and production of the F-16 fighter jet aircraft was formalized through a Memorandum of Understanding between the Government of the United States and the Governments of Belgium, Denmark, Netherlands and Norway in 1975 and was known as the Multi-National Fighter Program (MNFP). Portugal was later included in the program and the European part of the collaboration was named European Participating Air Force (EPAF). The collaboration was thought to be a way of extracting economies of scale in development and production of the new platform. It was also seen as a great opportunity for smaller Nations to join in a common acquisition of the new system as this would give them greater negotiation power towards the industry. The fact that the collaborating Nations were able to agree on a common configuration is seen as the key success factor of the program as this was crucial to realize gains from scale. The collaboration was later extended beyond the procurement phase and now involves cooperation in deployments and operations. This has led to a closer integration of the Member Nations' systems and a higher level of standardization of equipment through common training, maintenance and upgrades, increasing the gains from scale further.

The obvious cost advantages of the common development of equipment have already led to extended cooperation in this field, illustrated by the common acquisition of F-16 described in the fact box. But as the fact box also indicates, even larger gains can be achieved by not limiting cooperation to the area of acquisition. In order for economies of scale to be fully exploited in the production of defence commodities and services in the Alliance, closer cooperation in all areas of defence must be considered. There are examples of cooperation in the Alliance where Nations have co-developed and co-produced military equipment, but failed to maintain a similar configuration for the remaining lifecycle of the system produced, hence missing out on gains throughout the lifetime of the products [26].

As described earlier, economies of scale can be large when starting from a low level of production. This has implications for the development and investment in new technologies as the low initial demand for a defence good (due to challenges such as tight budgets) may prevent Nations from investing in new production technologies. The substantial fixed costs may keep Nations from making the necessary investment,

even though it would considerably reduce the variable costs. As the quantity produced is low, the investment is not considered cost efficient. By cooperating, a group of Nations can increase total demand, making the investment financially justifiable.

This is illustrated in Figure 3-2, where AC1 represents the average unit cost curve of a production process with apparently a low ratio of fixed costs compared to variable costs, such as the initial production technology. AC2 represents the average cost curve of a production process with a high ratio of fixed costs to variable costs, like the more efficient but expensive technology[2]. If expected demand, and thus production, increases above the intersection point of the two curves (point A in Figure 3-2) the new production technology will lead to unit costs that are lower than the original production process making the investment in the new technology worthwhile. From a military perspective this mechanism could be particularly important for small and medium-sized Nations. For instance, a training simulator can replace some expensive live exercises but without cooperation the initial investment could be too high for many Nations.

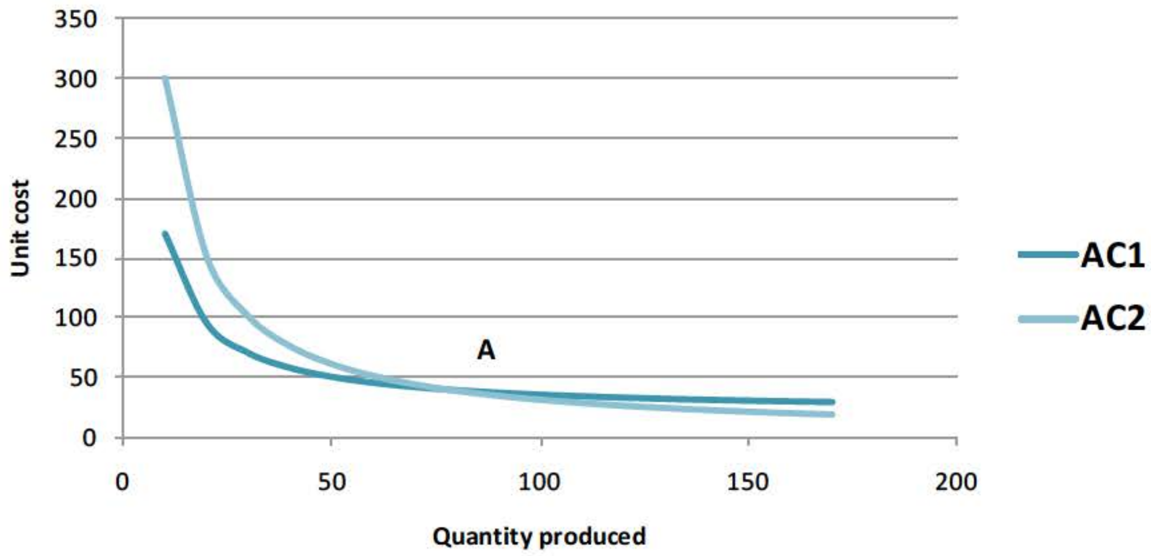


Figure 3-2: Average Unit Cost Curves Before and After Investment in New Technology.

Another source of economies of scale is the division of labor. As an activity is increased or production grows larger, the labor force will have to be expanded. The expansion creates opportunities for each employee to specialize in a smaller number of tasks. For instance, if one team is responsible for both engine repairs and navigation systems on a certain platform type, an increased workforce might give room for two specialized teams, and as a consequence employees will be more efficient in their work. This specialization process will also lead to gains from learning effects, meaning that the employees get better, and thus more productive, the more times they perform the task. Learning effects will be covered further in Section 3.1.3. The pooling of the maintenance of military systems is a typical candidate for this type of benefit from scale.

Finally, there are large potential cost savings from economies of scale by specialization of activities, i.e. by pooling two countries' defence activities or similar production processes in the country with the lowest average cost curve. This concept of utilizing each other's comparative advantages is the rationale for all trade. To illustrate this idea consider the production process in Country 1 described in Figure 3-1. Assume that for the production of the same goods, another country, Country 2, is less productive than Country 1. The higher production costs result in a variable cost of production in Country 2 of 10 dollars compared to

[2] Assumptions: AC1 has a fixed cost of 1500 and a variable unit cost of 20. AC2 has a fixed cost of 3000 and a variable unit cost of 1.

Country 1's three (3) dollars. In addition to this, it is assumed that fixed costs amount to 1500 dollars. The average unit cost curves of the two countries are illustrated in Figure 3-3.

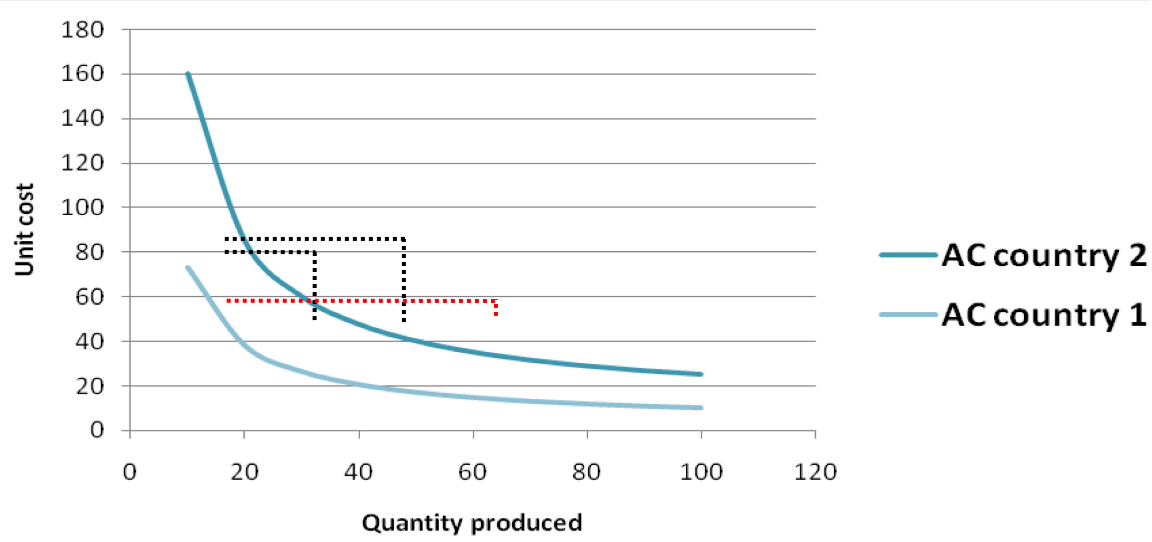


Figure 3-3: Economies of Scale and Gains from Pooling Production.

Assume that Country 1 has an initial production of 20 units, while Country 2 initially produces 40 units. The unit costs are indicated in Figure 3-3. Now, assume that the low production volume in Country 1 implies that there is excess production capacity in their facilities and no investments are needed to boost production. By pooling all production in the low-cost Country 1, the unit costs in Country 1 and Country 2 fall from 38 and 48 dollars respectively, to approximately 15 dollars, a 28 percent reduction for Country 1 and a staggering 47 percent reduction for Country 2. This is illustrated by the red dotted lines in Figure 3-3.

So far, it has been shown that larger-scale effects are achievable when the fixed costs are high. This will especially apply when production numbers are low, and typically near the critical mass of the production. On almost every major weapon system some Allies face the critical mass problem, thus such systems should to a larger extent than today be candidates for extensive cooperation through collocation, either as Type-I or Type-S. The cooperation should also be organized to benefit from comparative advantages.

3.1.2 Economies of Scope

Economies of scope are closely related to economies of scale, but the implications are somewhat different. Economies of scope are defined as the benefits that arise from carrying on related activities [38]. Where economies of scale are known as declining unit costs due to the sharing of fixed costs on more units produced, economies of scope occur in production processes where it is less costly to combine two or more product lines in one place than to produce them separately. The gains from economies of scope are thus related to the utilization of common resources. By gathering production of two or more products, the production process can be undertaken more cost efficiently.

Economies of scope in the defence context could be exemplified by the establishment of common technical test centers for testing of military equipment. Both the facilities and the staff could be used to test different equipment of similar character, such as ammunition, explosives, etc. Another example could be activities requiring a high and costly technological level, such as the manufacture and maintenance of nuclear powered vessels and submarines.

As in the case of economies of scale, the cost structure of the activity or production process is an important factor in determining possible cost savings due to economies of scope. The gains will be largest in processes where the fixed costs common to the pooled production processes constitute a large share of the total costs. The marginal cost curve will also in this case be convex, so that the largest average unit cost reductions are found when the number of products produced with the same resources is low initially.

Fact Box: The Joint Strike Fighter Program

The Joint Strike Fighter program is an example of an international effort to increase scale in the production of military systems in order to reduce costs. Nine Nations are cooperating with Lockheed Martin to develop and produce the next generation fighter jets. These nine buyers are planning to acquire more than 3100 aircraft by 2035, a scale that neither of the partner Nations would be able to attain alone. The F-35 is being produced in three versions; the three planes are fundamentally different, but the goal is still to obtain approximately 80% commonality in order to reap gains from economies of scope and learning effects from the earliest phases of development.

Cooperation programs between Alliance members can be modeled in ways that also take advantage of the gains from economies of scope, allowing low-scale production in some fields to be maintained and justified. Economies of scope also provide a way to make small-scale production more efficient. As many areas of defence production within the Alliance are characterized by national specifications, joint production to generate economies of scale can be difficult to accomplish. Economies of scope will likely not result in gains of the same order of magnitude as economies of scale, but could in some cases be easier to implement, both from an organizational and political perspective. With similar arguments to those of economies of scale, organizing the cooperation programs as Type-I cooperation will likely lead to lower gains from economies of scope than programs organized according to Type-S cooperation.

3.1.3 Economies from Learning Effects

Learning curve effects, or learning by doing, are characterized by improvements in productivity, i.e. reduced unit production costs or increased product quantity or quality, due to increased experience in operating a process [38]. This can be summarized as the advantages that flow from accumulating experience and know-how. This means that gains from learning effects are dependent on the cumulative production, not the production level itself. As in the case of economies of scale, it is assumed that the gains from learning effects will be diminishing as accumulated production grows [39]. Figure 3-4 illustrates learning curve effects through the falling unit man-hour requirements in selected shipbuilding programs during World War II.

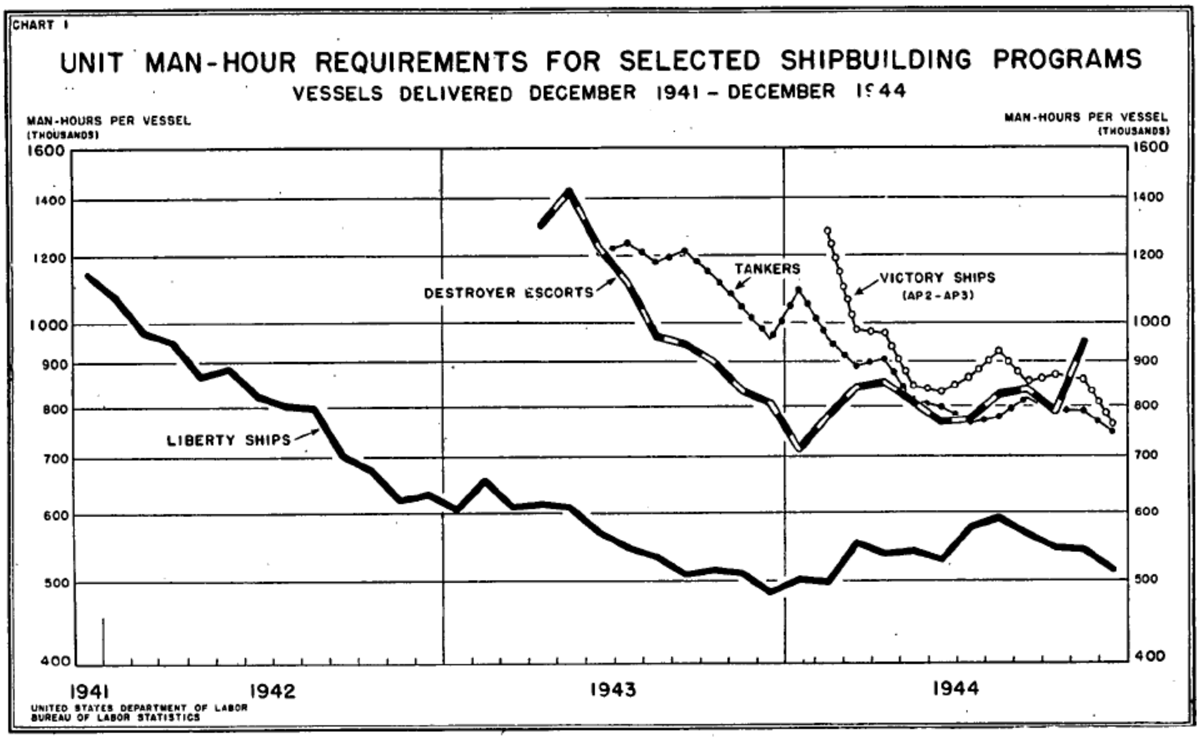


Figure 3-4: Unit Production Requirement on Selected Shipbuilding Programs During World War II [75].

Standardization is a key factor for extracting such learning effects in production. Standardization implies that variation in the designs of similar goods and services produced is minimized. By standardizing, the production process can be organized in a more optimal way, investments reducing the marginal cost can be made and staff will need less time to master their tasks. The more standardized the production process, the faster substantial learning effects will prevail. Examined projects with prolonged breaks revealed a shallower learning curve slope than the original program [68]. Analysis on the F-22 also points to a lower expected multi-year saving[3] (shallower learning curve) with significant configuration changes, such as block updates. [69]

It has been emphasized that the learning effects are tied to workers learning in production and can take place without any evident innovation in the production process [41]. Hence, these effects should be strong when production is labor intensive, i.e. a high ratio of labor to capital. However, Adler and Clark [40] have shown that the gains from learning effects can be just as large in industries that are capital intensive. This implies that cooperation efforts to gain cost efficiencies from learning effects should not only focus on labor intensive activities and production, such as maintenance. Gains can also be achieved from cooperation in fields such as training and exercises with advanced military capabilities like frigates.

As in the case of economies of scale, the size of the gains from learning curve effects is dependent on several factors. The largest gains from cooperation are usually found in areas where the initial accumulated level of production is low and where the cooperation leads to longer production series than each Nation, organization or firm could manage on its own. Co-locating several partners' production in one country or area as a result of cooperation agreements will allow longer production runs and thereby learning curve gains.

[3] Multi-year procurement contracts are awarded for several years at a time instead of single year contracting. The main benefits from multi-year procurement are claimed to stem from better opportunities for long-term production planning such as front end investments and training [70].

Though at times hard to separate, the differences between learning effects and economies of scale should be emphasized, as consequences of organizational changes in the two cases are different. Economies of scale are related to the cost structure of the production process, i.e. the ratio of fixed versus variable costs. This is not the case with learning curve effects. Large gains from increased experience and know-how can be realized regardless of the cost structure, because gains from learning curve effects are not related to the sharing of fixed costs but to a reduction in the variable costs. Nations should therefore not disregard cooperation in areas with a lower ratio of fixed costs, as there can also be potential cost efficiency gains in these areas of cooperation.

3.1.4 Economies from International Trade

Economic theory of international trade states that as Nations differ in their factor endowments, i.e. a country's stock of factors of production, technology and in their preferences for goods and services, there is an opportunity for trade that benefits all parties to the trade [42]. Trade allows for Pareto-improvements[4] as Nations specialize in production of the goods where they have a comparative advantage. A country has a comparative advantage in producing a good if the relative cost of producing the good, i.e. its opportunity cost in terms of other goods foregone, is lower than it is in other countries. These theories are also relevant for the discussion of international defence cooperation, as they point to the important issue of optimality in the organization of collaboration.

As an illustration, assume that the maintenance of armored vehicles and the maintenance of jet fighters are needed in two countries, Country 1 and Country 2, and that labor is the only input factor in these tasks. Country 1 has a labor force of high-skilled workers equal to one hundred working hours a month, while the less developed Country 2 has a similar workforce size but less skilled workers. The differences in the work force imply that Country 1 can perform the high-tech maintenance work more efficiently than Country 2. Assuming that the labor force is immobile between the two countries, Table 3-1 summarizes the maintenance output for the two different pieces of equipment in the two countries.

Table 3-1: Number of Pieces of Equipment Maintained in One Unit of Time in Country 1 and in Country 2.

No Cooperation	Armored Vehicles	Jet Fighters
Country 1	25	5
Country 2	25	1
Total	**50**	**6**

In this example, Country 2 lacks an absolute advantage in either of the tasks, a result of its lower-skilled workers. Still, for both Nations, there are potential benefits from cooperation through specialization and exchange of services.

The *opportunity cost*[5] of a fully repaired jet fighter in Country 1 is the maintenance of five armored vehicles. Alternatively, one repaired vehicle has the opportunity cost of 1/5th of a repaired jet fighter. In Country 2, the opportunity cost for the maintenance of the jet fighter would be the maintenance of twenty-five armored vehicles, while the maintenance of one armored vehicle has the opportunity cost of 1/25th of a jet fighter. This means that in order to repair more units of armored vehicles, Country 1 has to give up a larger amount of jet fighter maintenance than Country 2. Country 2 has a comparative advantage in maintenance of armored vehicles, while Country 1 has a comparative advantage in maintenance of jet fighters.

[4] A Pareto improvement implies a raise in the welfare of some without the lowering of the welfare of anyone else.

[5] Opportunity cost is the cost of an activity measured in terms of the value of the forgone alternative.

Assume that before the two countries engage in cooperation, they spend half their workforce on each of the two tasks. The total production is summarized in Table 3-2. Assume now that the exchange of repaired military equipment could be achieved cost-free between the two countries. By engaging in a Type-S cooperation arrangement, the two countries could specialize in the task where they have a comparative advantage and exchange the repaired equipment between them afterwards. This would increase the total production of fully repaired armored vehicles and fighter jets in the two Nations.

Table 3-2: Number of Pieces of Equipment Maintained in Two Units of Time by Country 1 and Country 2 in the Case of Specialization and Cooperation.

Specialization and Exchange	Armored Vehicles	Jet Fighters
Country 1		10
Country 2	50	
Total	**50**	**10**

The model and this example are of course a gross simplification of reality and factors not included will undoubtedly complicate the picture. However, the example does provide an illustration of the principles of trade theory and shows why trade, or the exchange of goods through arrangements such as cooperation, can be highly beneficial to Nations engaging in them.

The model rests on an assumption of limited factor supply. Each country has a labor force equal to 100 working hours a month in the example above. Gains from trade are generated by optimizing the use of these scarce resources. If Country 1 had excess labor not being used, it could put this labor into repairing its armored vehicles, without it being at the expense of the maintenance of its fighter jets. The assumption of resource scarcity is highly relevant, as the discussion of defence cooperation really is a discussion of the most efficient way to organize a limited amount of resources available for defence within the NATO Alliance. Despite the simple model, the example illustrates an important question for national governments to consider: could resources allocated to the production of certain defence goods and services make a greater contribution to the national economic welfare if used abroad?

3.2 BEYOND THE ECONOMIC BENEFITS

In financially challenging times, cooperation efforts tend to focus on extracting the economic gains, i.e. the cost savings. However, incentives for cooperation across national borders in the area of defence are not just limited to the obvious economic benefits described above. There have been, and will in the future also be, cooperative initiatives motivated by the operational and the political benefits that Nations can derive from them.

3.2.1 Operational Benefits

One of the main reasons for joining forces in operations is, of course, the increased combat capability that may result from the cooperation. Benefits can be achieved through cooperation on procurement as well as support activities.

Procurement collaboration programs organized as either Type-I or Type-S can be greatly advantageous as they can give some countries access to technologically advanced equipment that would otherwise be too costly to develop or acquire. In addition, cooperation leading to the technological harmonization and standardization of military equipment between the collaborating partners enhances interoperability and the

ability to collaborate in the future. Case Study #3 in Chapter 5 illustrates that there can be substantial operational gains when Nations operate on standardized equipment. The value of standardization is also well known in logistics, where it has long been recognized that by acting together or by giving one partner the responsibility of supplying the others, either in operations or through support activities, Nations can also substantially reduce their total logistic footprint achieving both cost savings and operational gains [65].

Fact Box: NATO Defence Planning Process[6]

Defence planning in the Alliance is an essential instrument which enables the organization to develop and deliver the necessary forces and capabilities needed to achieve its objectives. The aim of the NATO Defence Planning Process is to provide a framework within which national and Alliance defence planning activities are harmonized and synchronized to meet agreed targets in the most effective way. The process is an example of a cooperation effort organized to achieve operational benefits.

The NATO Defence Planning Process consists of five steps having basically a sequential and cyclical nature. The first step consists of establishing political guidance reflecting all political, military, economic, legal, civil and technological factors which could impact the development of the required military capabilities. Furthermore, the associated priorities and timelines required given NATO's Level of Ambition are defined clearly at this stage.

The next step in the NATO Defence Planning Process is the preparation of a single consolidated list of minimum capability requirements before an apportionment of the identified requirements and setting of targets. Target setting initially apportions the overall set of minimum capability requirements to individual NATO Nations and NATO entities in the form of target packages. During the apportionment process, each individual Nation has the opportunity to seek clarification on the content of targets and present its national views. Based on the iterative dialogue between NATO authorities and Nations, refined and individually tailored draft target packages are forwarded to respective NATO Nations.

The following step consists of organizing and providing national, multi-national or collective efforts to satisfy agreed targets and priorities. The aim is to focus on addressing the most important capability shortfalls. The review of results is the final step and seeks to examine the degree to which NATO's political objectives, ambitions and associated targets have been met and to offer feedback and direction for the next cycle of the defence planning process.

NATO obviously plays a decisive role, both as a facilitator and "clearing house" for future cooperation and the NATO Defence Planning Process could become an important avenue, together with Smart Defence, for initiating new international cooperation programmes. However, details of how NATO could develop this work to promote such initiatives go beyond the scope of this report.

Standardized equipment can also enable shared training and doctrines, which will further increase interoperability within the Alliance [46]. In general, cooperation in several areas such as training and maintenance for operations, have the potential to foster the development of common doctrines and

[6] For further information on NATO Defence Planning Process, see Annex E.

procedures, thereby strengthening not only efficiency but also the sense of solidarity and trust within the Alliance. Successful cooperation could thus be viewed as a foundation for further cooperation.

Common operations also promote a higher degree of similar thinking, a common strategic culture, and shared experiences which may strengthen the foundation for further cooperation. Another, less obvious, operational gain of collaboration in operations is the valuable experience that this brings about for smaller Nations [52]. For some Nations, the experience gained through collaborations can trigger reforms or at least offer insight into how to reform the national armed forces [53].

3.2.2 Political Benefits of International Defence Cooperation

The political considerations for international defence cooperation are numerous and could just as well be the subject of an entire report. Political factors are highly influential in a country's decision to engage in international cooperation. In this context the present discussion is limited to political benefits related to security and industrial policy.

3.2.2.1 Security Policy Benefits

International defence cooperation can strengthen political-military ties between Nations and increase trust. According to the report *Maximising the benefits of defence equipment co-operation* by the Comptroller and Auditor General in the British Ministry of Defence [46], French, German and Italian officials outline the belief that defence equipment cooperation had a crucial role to play in the development of the EU's Common Foreign and Security Policy and the European Security and Defence Identity.

Engaging in international defence collaborations can be a way for a country to build stronger relationships with its trade partners, positioning itself in large organizations such as the EU. Contributing to the success of a defence collaboration program can also be a way for a country to strengthen its image as a reliable and credible collaboration partner.

3.2.2.2 Industrial Policy Benefits

Participating Nations' views of the outcome of a collaboration program will often depend highly on not only the economic gains, but also the effect on their respective national industry and technological base. The potential industrial benefits depend largely on the type of cooperation, its organization and the level of integration.

In a Type-S specialization arrangement, countries have the chance to improve their production in one or more areas in which they have a comparative advantage. Specialized but increased production in a limited number of areas strengthens national industries, and creates jobs to the benefit of local communities. This type of arrangement also allows countries to redirect resources from inefficient production processes to more efficient and larger processes.

In a specialization scenario, as described above, the cooperation between Nations is limited to high-level negotiations and contracting. More commonly, however, cooperation programs include co-development and/or co-production, features of a Type-I cooperation. In addition to the issues of the security of supply and the retaining of military competence, projects organized by work-share agreements of Type-I are not necessarily cost efficient. However, they can have positive effects on national employment and the defence industrial base, as well as be of importance for governments attempting to uphold or even strengthen marginalized local communities. Decision-makers should be cautious when weighting industrial aspects against cost efficiency, as subsidizing inefficient industry might have short-term benefits and long-term negative consequences. Several reports have argued that the European defence industrial base is subsidized, inefficient or suffers from counterproductive intra-European trade regulations [9], [25], [56] and [57].

Other benefits of co-production, especially when done in a tightly integrated manner, can include higher levels of technology sharing and knowledge spill-over between collaborating Nations. Technology sharing is a strong incentive for Nations to join cooperation programs, as this can give access to otherwise withheld technological developments. Technology sharing also contributes to minimize capability gaps within the Alliance, increasing the capability of the Alliance as a whole. Knowledge spill-over between Nations can increase efficiency in production (i.e. learning curve effects), increase innovation and thereby not only lead to possible cost reductions but also quality improvements in terms of military effect.

Closely integrated cooperation, especially in fields such as acquisition, will also be of interest to governments and large companies wishing to establish themselves as suppliers in industrial areas that are new to them. Other benefits include the expected advantageous spill-over from defence industry to civilian national industry.

Offset arrangements are defined as the agreements between Nations leading the supplying Nation to place work with firms in the buying Nation, over and above what it would have done in the absence of the offset agreement. Where cost efficient, offsets could be used as means to ensure reciprocal trade. However, a warning should be given about the pitfalls, as offsets could be used to subsidize inefficient industries, hence reducing efficiencies. There are benefits beyond the economic ones that make offset arrangements appealing to some Nations. By claiming offset agreements in exchange for joining a cooperating club or Alliance, a country can ensure that part of its defence industry is kept alive. This can allow a country to become a niche producer within a specific area of defence, strengthening the related industries instead of gradually losing the Nation's capacity in this area.

Fact Box: Offsets in US Defence Trade

The report *Offsets in Defence trade – Sixteenth Study* by The US Department of Commerce [58] states that in 2010, US defence contractors reported entering into 24 new offset agreements with 12 countries valued at 2.04 billion USD. The value of these agreements represented 63.52 percent of the 3.21 billion USD in reported contracts for the sale of defence goods and services to foreign entities with associated offset arrangements. In 2012, US firms reported 690 offset transactions[7] with 28 countries with an actual value of 3.61 billion USD, and an offset credit value of 4.42 billion USD.

The US Government policy on offsets in defence trade states that the US Government considers offsets to be "economically inefficient and trade distorting" and prohibits any agency of the US Government from encouraging, entering directly into, or committing US firms to any offset arrangement in connection with the sale of defence articles or services to foreign governments. However, the report claims that export of defence articles and services as a result of offset arrangements can lower overhead costs for the US DOD, help sustain production facilities, workforce expertise, promote interoperability and contribute positively to US international account balances. According to the report, US defence contractors generally see offsets as a reality of the marketplace for companies competing for international defence sales.

All multi-national defence cooperative programs rely on a certain level of trust between the collaborating partners. The required level of trust depends on the type and the level of cooperation. However, trust is not

[7] Transactions conducted to fulfill offset agreement obligations.

only a requirement but also a by-product of successful cooperation. By initiating cooperation on lower levels, trust between partner Nations can be built leading to closer and more radical cooperation in the future.

Lack of trust has already been recognized as one of the reasons for the currently limited level of close defence cooperation between Member Nations of NATO. But the lack of sufficient levels of trust can also lead to increasing costs when attempting to implement a cooperation program.

3.3 SUMMARY OF BENEFITS

In this chapter, the potential gains that can be made from international cooperation are highlighted. The main types of gains are economies of scale, scope and learning. The chapter also discusses possible operational and security policy gains. The biggest driver behind securing the largest possible gains is the large share of fixed costs. That way, when the production increases one can distribute these fixed costs over an increasing number of units. Areas in the armed forces that are close to critical mass, that have large development costs, or where the marginal cost of adding another unit is small, will thus be areas where there will be large benefits from cooperation.

The next chapter will discuss the costs of cooperation, starting with the economic factors, before looking into the non-economic factors.

Chapter 4 – COSTS AND BARRIERS OF INTERNATIONAL COOPERATION

The benefits of international military cooperation discussed in Chapter 3 are many and well recognized. In light of these recognized benefits, the number and scope of cooperation initiatives in NATO can only be characterized as surprisingly low and unambitious. Why is it the case that despite the obvious benefits from cooperation, the results are lacking?

The answer might in part lie in the heterogeneous nature of the different NATO Nations and in part in the transaction costs related to cooperating internationally. In many cases the perceived costs simply outweigh the benefits. Thus, recognizing both the existence and importance of these show stoppers is in itself important, and will aid in identifying the best cooperation efforts as well as the right partners for the effort. This insight might then in turn lead to a larger number of initiatives in NATO, simply because the decision-makers know what makes or breaks a cooperation effort.

In this chapter, the most important transaction costs related to international cooperation are identified and the question of how diversity among Member Nations might drive up these costs is discussed.

4.1 ECONOMIC COSTS

Chapter 3 demonstrated that economies of scale and scope, as well as learning curve effects, can lead to large cost savings or to increases in the quality of the goods and services being provided. However, in order to understand the potential outcome of different forms of cooperation, the barriers preventing cooperation and the costs of carrying it out must also be taken into account. Trade barriers and transaction costs in particular are examined more closely in this section.

Trade barriers are recognized as the laws, institutions and practices that make trade between countries more difficult or expensive than trade within countries. Free trade implies trade free from trade barriers, with no tariffs or subsidies on imports or exports, and no quotas or other trade restrictions. Transaction costs can be defined as the costs of making an economic exchange. Gains from trade can be fully offset by these barriers and transaction costs. When this is the case, self-sufficiency becomes the rational option from an economic point of view. Hereafter, the concepts of trade barriers and transaction costs are discussed further in light of the different types of cooperation. Some of the most important driving forces behind trade barriers and transaction costs are also identified.

4.1.1 Cost Resulting from Trade Barriers

As stated above, the gains from cooperation depend on the Alliance members' willingness to give up self-sufficiency. If cooperation is organized in the right way, their economic benefits can be substantial – but, as in the international market for civilian goods and services, barriers of trade in defence cooperation complicate the picture. One key insight in this matter is that conflicts of interest within Nations are usually more important in determining trade policies than conflicts of interest between Nations. The relative power of different interest groups within countries is often the main determining factor in government policies toward international trade, rather than the overall interest of the Nation [59]. Strong interest groups such as unions will lobby for the Nation's share of contracts in a collaboration agreement in order to save jobs or to keep wages high. The national defence industries will lobby for their involvement in R&D in order to gain insights into new technologies and to reach new markets. Decision-makers who let the interests of smaller groups weigh more heavily than the potential cost efficiency gains from cooperation can be tempted to protect national production by introducing, upholding or increasing already existing trade barriers. This situation leads to the implementation of economically less efficient policies such as policies to limit international trade.

4.1.2 Transaction Costs

While trade barriers in most cases are the result of choices made by decision-makers who wish to reduce international trade in order to protect national interests, transaction costs are the excess expenses related to the process of the trade. Transaction costs can thus be defined as the costs of making an economic exchange, or the costs of sustaining an economic system.

The size of the transaction costs will most likely vary with the number of participants in the cooperation, the composition of the cooperation group, the type of activity that is the focus of the cooperation and the organization of the cooperation. The contributions of economist Ronald Coase to the understanding of transaction costs are worth mentioning. Coase [60] introduced the term transaction costs, and related the term to the question of differentiating between the activities that should be performed within an organization, and the activities that should be performed by the use of a third party. He questioned why firms bother hiring employees if the market is really as efficient as it is claimed and suggested that firms hire people because transactions that are conducted outside the organization will be subject to costs. These costs are related to searching for suppliers, bargaining, enforcing quality standards, etc. The same reasoning applies to cooperation between defence forces.

The driving forces behind trade barriers and transaction costs are numerous and complex. The following section highlights the most important factors determining the costs related to international defence cooperation.

Fact Box: EU Defence Procurement Directive

In order to establish a more efficient European market for defence procurement and at the same time to secure a competitive defence industry, a new defence Procurement Directive (PD) has been adopted in the EU. The directive is now being implemented by the member countries.

The rules of the directive apply to any supply or service contract above 412,000 Euros and any works contract above 5.15 million Euros. However, some procurements can still be exempted from the directive based on Article 346 of the Lisbon Treaty, allowing a member state to shield a defence buy from the new rules if deemed critical to national security. The incentive of the directive is to open the European defence market to EU-wide competition in order to gain economic savings through reductions in transaction costs for procurement projects and in the trade barriers between countries.

The EU defence PD seems to be a step in the right direction even though critics suggest exemptions are routinely invoked for the benefit of national defence industries [25].

4.1.3 Driving Forces Behind Trade Barriers and Transaction Costs

4.1.3.1 Mark-Ups Tied to Specificity of Assets

Asset specificity can be defined as the degree to which the investments made to support a transaction have a higher value to that transaction than for other purposes. If one party makes investments in order to carry through a cooperation arrangement with another country, and this investment is of most value when used for this purpose, the assets involved are specific for that transaction. The implication of asset specificity is that one party to some extent is bound by the transaction, and is vulnerable to opportunistic behavior from the other party.

Opportunistic behavior might materialize in cases where one party is tied into the cooperation through large investments in cooperation-specific assets, and the other party uses this to strengthen its own negotiation position after the assets are acquired. This problem can arise regardless of cooperation type. Consider as an example the case of cooperation between two countries on a joint maintenance facility where one country, Country 1, houses the facilities and finances most of the construction of these facilities. After the maintenance of both countries' systems has started, the armed forces in the second country, Country 2, might fall on hard financial times. In order to save funds, they could ask Country 1 to bear a larger part of the costs related to the maintenance facility. Country 1 would have little choice but to accept this, as their costs would be larger if Country 2 left the collaboration. Both parties will be aware of this before agreeing to the deal, and might safeguard themselves with stringent contracts or excessive risk mark-ups on the cost.

4.1.3.2 Private Benefits

In economics, goods are divided into private goods and public goods based on two characteristics: excludability and rivalry. A public good is one where the marginal cost of providing it to an additional person is strictly zero (non-rival), and where it is impossible to exclude people from receiving the good (non-excludable) [42]. Services such as radio transmissions are pure public goods. Private goods are goods that are recognized as either excludable or rival, or both. If the benefits arising from international defence collaboration are public, meaning that other countries cannot be excluded from enjoying the benefits of the cooperation and that the benefits for some do not crowd out the benefits for others, the problem of free-riding may occur. Examples include strategic air defence systems or nuclear deterrents. The special features of public goods generate incentives for free-riding by the actors with a lower willingness to pay for the good. As a result the supply of such goods can be less than optimal, i.e. there could be an underinvestment in, for instance, strategic air defence systems.

Olson and Zeckhauser [43] analyze the good of nuclear deterrence, and find that since this good is partly non-rival and non-excludable, the defence expenditure in NATO is lower than would otherwise be the case as some members bear a smaller share of the common burden than their size would entail. This is because Nations have the possibility to free-ride and spend less on defence, and still be covered by NATO's nuclear umbrella. Forbes and Sandler [44] expand this model significantly by arguing that modern conventional weapons are partly excludable and rival. This has led to a new understanding of the nature of defence goods, the joint product model, where a part of the defence spending benefits only the spender.

Most defence goods will have elements of being either excludable or rival and the issue of free-riding should not be of great concern when countries consider engaging in cooperation. However, the problem should be recognized when viewing the NATO cooperation as a whole. In order to increase the efficiency of NATO's main tasks, the issue of free-riding should be taken seriously.

4.1.3.3 Inefficient Work-Share Arrangements and Rent-Seeking Behavior

Economic actors are said to seek rent when they try to obtain benefits for themselves through the political arena. A major impediment to realizing economies of scale in cooperation agreements with several Nations involved is the widespread use of work-share arrangements between the participating Nations and the subsequent rent-seeking. A common principle of cooperation agreements is that each Nation receives the same percentage of industrial contracts as the Nation's share of purchases from the project. The possible benefits for one single country from co-production may be the technology transfers to national industry, the contribution to employment and the enhanced balance of payments, but this practice, called *juste retour*, usually results in inefficient production allocation [2]. The economically optimal solution would be to locate all production at that single location where production is achieved most efficiently. Dividing up the business and locating it in several countries will potentially reduce the amount of economies of scale in the project. The issues arising from this type of arrangement increase with the number of participants, as the production will be divided amongst more and more Nations. This applies both to international acquisition projects and other collaboration activities, for instance on maintenance and training.

Another source of cost inefficiency in production is offset arrangements. Offsets are defined as the agreements between Nations leading the supplying Nation to place work with firms in the buying country, over and above what it would have in the absence of the offset agreement [45]. These offsets are usually designed to achieve a relocation of economic activity from the supplying Nation to the purchasing Nation and can be seen as a trade barrier. Protection of national industry is an argument for Nations to bargain for offsets when buying defence goods and services abroad. If these offsets are not generated on the basis of a cost efficiency goal, they will generally reduce the overall efficiency gains from the cooperation. However, offsets need not be inefficient and welfare-reducing in all cases. In a world of perfect competition, such agreements would lead to efficiency losses, but in reality offset agreements can reduce existing trade barriers between the trading countries and extend market information and knowledge.

Fact Box: Lessons Learned from the Euromav Initiative

Denmark, Germany, Italy, the Netherlands, Spain and Turkey signed a Memorandum Of Understanding (MOU) in 1984 for the co-production of the US developed air-to-ground Maverick missile.

The Maverick cooperation was set-up as a rigid *juste retour* type work-share agreement where each Nation's share of total acquisitions was to equal its work-share and cost-share. The initiative was terminated in 1988, after years of negotiations and tender processes. The rigid work-share requirement was one of the main reasons for the failure of the project because it prevented the project from benefiting from the lowest cost compliant tender. This failure to take advantage of each other's comparative advantages made the unit price of the missile higher than the "off-the-shelf" price tag from the US, even after excluding the non-recurring cost of the transfer of technology and industrialization. An additional challenge to the negotiations was the fluctuation in currency exchange rates, which made it difficult to adhere to a fixed work-share. More details of the Maverick cooperation initiative can be found in Annex F.

4.1.3.4 Enforcement of National Standards

The prevalence of national standards is another barrier for defence cooperation. This can be compared to civilian trade barriers, such as the protection of national industry through customs regulations. Country-specific standards are a result of differing military requirements due to differing needs, but other incentives also come into play. For instance, national defence industries, unions and other interest groups have strong incentives for keeping the national standards, as the standards protect national production and thus labour.

National standards related to defence equipment and national specifications can thus be seen as obstacles to efficient cooperative solutions. The absence of a common standard for defence goods and services within NATO, including tactics, weapons, training and logistics, creates additional costs and complications for cooperation agreements and leads to the waste of scarce resources [45].

4.1.3.5 Geographical Distance and Transport Costs

Transport costs are the costs of moving goods from one place to another and are important drivers of overall transaction costs. These costs are usually defined as the monetary measure of expenditure related to the transport of goods from the supplier to the market or to the demander, but the term can also be used to describe the fall in product quality as goods are transported from one location to another. When transport costs are high, it is economically efficient to produce close to the market.

The costs of transportation depend on several factors, including the distance and accessibility of the destination, the type of good transported, energy prices and existing competition in the transport sector. However, the costs of transport can be reduced substantially when taking advantage of economies of scale, for instance by transporting more goods at once and minimizing the spare capacity of containers.

Transport costs are highly relevant when considering international military cooperation and can at times be of such magnitude that countries are better off producing the goods themselves.

4.1.3.6 Creation of Monopoly Suppliers

It was shown in Chapter 3 that international cooperation can generate large gains from economies of scale and learning curve effects, and should therefore be of great interest to decision-makers. But with economies of scale comes a breakdown of the competitive market. Pooling of production as a way of extracting gains from economies of scale will simultaneously generate monopoly power for the chosen supplier. Inevitably there will be a long-run trend towards a smaller number of larger defence contractors, leading to the departure from an advantageous competitive market model [45]. The generation of monopoly power implies that the supplier, a firm, an organization or a country, can act as a *price setter* rather than a *price taker*, capable of raising prices to levels where the gains from economies of scale are completely outweighed.

The issue of market failure is less relevant when considering the broad definition of defence goods and services, as most defence products are not commodities traded on the market. In the case of air surveillance, for instance, the state is both the producer and the consumer and hence there is no pricing and no real exchange of goods. On the other hand, in the case of a defence cooperation that includes the industry, such as the common development of defence equipment, the pooling of production can generate monopoly power for the chosen supplier, leading to a breakdown of advantageous competition and a likely cost increase for the buyers. The creation of monopolies may also lead to a lack of diversity in supplied goods and services, implying a loss of options and thereby a fall in utility.

4.1.4 Number of Participants and the Cost of Managing Multi-National Projects

The cost drivers described above are all affected by the number of partners involved in the cooperation project. With multiple Nations come multiple standards, regulations, schedules and national interests. The larger the number of partners involved, the more factors there are to consider and agree on, such as Nation specific standards, contract related work and international work-share arrangements. This especially applies to international acquisition projects. The British study *Maximizing the benefits of defence equipment co-operation* [46] examined how the development costs were influenced by the number of international participants. It concluded that the development costs in some cases were twice as high as comparable national projects. Costs also increased because participants added specifications during the development. These costs increase with the number of participants, as the likelihood of differing national preferences increases with the number of Nations in the cooperation.

According to Cothier and Moravcsik [47] a common rule of thumb for the estimation of cost increases in multi-national projects is that the unit cost of a weapon system increases by the square root of the number of countries participating in its development. The authors claim that the estimate has no basis in research, but can still be valid as an ROM estimate of the increasing costs reported in several empirical studies.

The relation described above is illustrated in Figure 4-1 by a total development cost that increases dramatically with the number of participants. This is merely an example, based on the observed relation between the number of participants and development costs. Economies of scale and learning curve effects will reduce average unit cost, but the costs for each participating Nation, assuming development costs are distributed evenly, will fall more slowly than if there were no transaction costs involved in the cooperation effort.

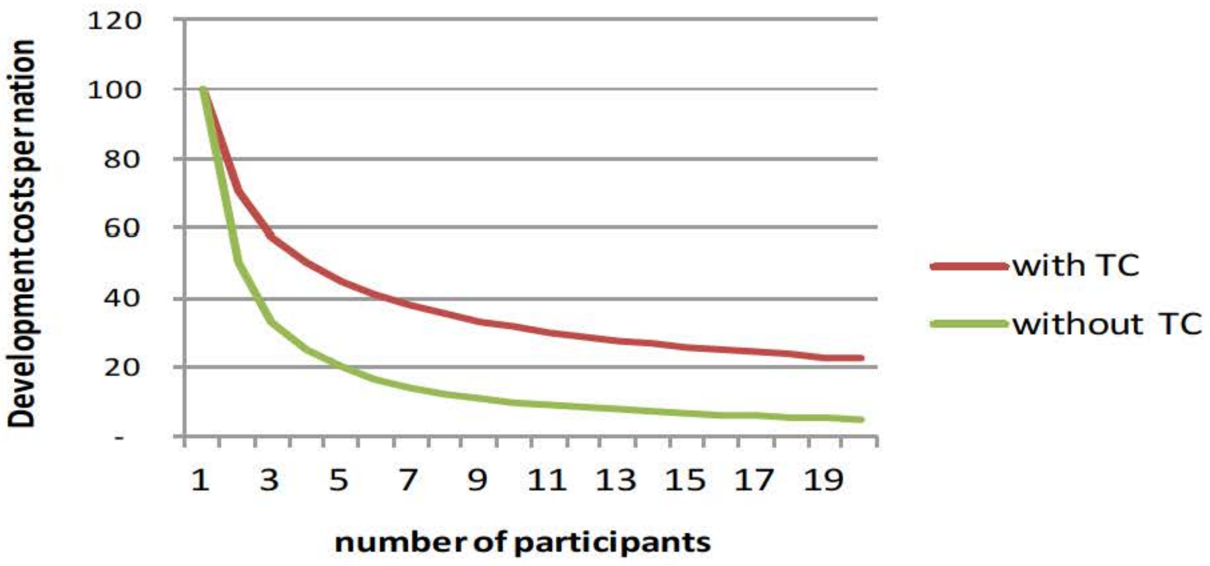


Figure 4-1: Example of Development Costs Per Nation With and Without Transaction Costs (TC) 100 = Costs with Only One Nation.

As seen in Figure 4-1, even though these kinds of transaction costs reduce dramatically the gains from cooperating, they far from completely remove them. For example, at four participants and no transaction costs, the cooperation would yield a saving of 75 percent of the total development cost. Instead, with these transaction costs, the end result is a 50 percent saving.

Development costs and development time are closely interlinked. The increasing costs of a development program may delay the entire program, and in a similar way a delay in many cases may increase the total costs of the program. Hartley [45] suggests that the development time is a function of the project development cost, the number of partners in the cooperation and the characteristics of the defence equipment.

Hartley claims that development time grows as a result of delays due to frequent meetings and paperwork, the need to consult all the partner Nations and the slow decision-making process by "over-involved" governments. The expanding costs and time delays following an increased number of participants imply that the advantages of increased scale following a larger cooperation could be completely outweighed. This should be taken into account when considering the scope of a collaboration program.

In addition to the reasons mentioned above, an increased number of collaboration partners has a tendency to increase both the total development cost and the development time because of the additional cost and effort that goes into searching for cooperation partners, conducting business across borders and languages, drawing up contracts, negotiating the deals and following-up on the terms of the deal. These are costs not experienced when an activity is performed within a country's armed forces. These costs are likely to be greater the more complex and larger the cooperation program or arrangement.

4.1.5 The Impact of the Cooperation Type on Drivers of Transaction Costs and Trade Barriers

In a Type-I cooperation, the partners in the cooperation arrangement are cooperatively responsible for development and production; they produce the defence good in question together. In a Type-S cooperation, only one or a limited number of partners are responsible for developing and producing the defence good in question. As discussed previously, when several partners are involved in the development and production process, there is a greater need for coordination, well-functioning communication and interoperability on all

levels. As a result the costs of cooperating are likely to be higher than if only one or a limited number of partner Nations are in charge. In a Type-S cooperation on the other hand, intensive contracting is required on a higher level prior to the agreement. In this respect, a Type-I cooperation may encounter greater transaction costs as a result of the larger number of cooperating Nations. However, the disadvantages from cooperation are not just the economic costs. In fact, non-economic disadvantages are often the reason why cooperation is not initiated, or if initiated, organized in a less cost-efficient manner.

4.2 NATIONAL DIVERSITY AND COOPERATION COSTS

Another important cost driver and show stopper for many cooperation initiatives in NATO is the diversity observed in NATO Nations. The following section discusses a number of dimensions along which the Nations tend to differ. Later the report discusses what this might imply for the choice of cooperation partners and cooperation type.

4.2.1 Military Ambition and Doctrines

Differences in military ambition and how operations are conducted, i.e. doctrines, are important factors for the success or failure of a cooperation initiative. Military ambition and doctrines could be said to be a result of political ambitions, culture and history. The differences might be multi-faceted, but some main characteristics seem to be dominant. These include regional focus, i.e. expeditionary mobile focus versus stationary national territorial defence, willingness and eagerness to engage in operations, the approach to the use of force and the attitude towards risk in theater, the latter being widely discussed [8], [29], [30] and [31].

In *Surviving Austerity – the case for a new approach to EU military collaboration* [25], Valasek emphasizes factors related to military ambition when he points to *similarity of strategic culture* and the *seriousness of intent* as success factors of past partnerships. Valasek's findings are based on key lessons from past and present examples of cross-border defence cooperation based on interviews with former ministers of defence, political directors, EU and NATO officials, soldiers and diplomats.

In *Lessons learned from European defence equipment programmes* [3], Darnis et al. points to the importance of convergence of elements of Nations' military doctrine as key to successful cooperation. Similarity in these areas will more easily lead to consensus on requirements, and thus common equipment, education and training regimes, caveats of common operations, etc.

Likewise Kincaid et al. suggest that pooled forces are important drivers of interoperability, common doctrine and equipment [9]. Hence, obstacles related to interoperability, equipment convergence, doctrines and military ambitions are not static, but there seems to be an important interplay between them that should be addressed in every cooperation effort. In *Innovative approaches in logistics* [66], De Nijs underlines that cost efficiency gains could be attained not only by focusing cooperation around 'material' capabilities, but also through standardization and interoperability in the 'non-material' part of the DOTMLPF spectrum[1].

Widely differing ambitions can affect the level of trust between countries, as potential conflicts of interests are more likely. Operation Unified Protector in Libya in 2012 demonstrated this principle, when Nations opposing the war withdrew national resources from some common NATO assets [31].

4.2.2 Technological Level

An uneven technological level between the Nations involved in a cooperation program is another factor that can be a challenge for its implementation. Differing technological levels could be measured both in terms of technological maturity level and in the capacity to undertake large projects, such as development and

[1] DOTMLPF: Doctrine, Organization, Training, Materiel, Leadership, Personnel, Facilities.

production of fighter aircraft. Valasek brings up the former when stating that countries with advanced militaries will want to work with equally sophisticated partners [25]. Lorell and Lowell emphasize the latter as an important characteristic determining the outcome of cooperative procurement programs in *Pros and cons of weapons procurement collaboration* [26].

The degree to which differences between countries can generate difficulties in cooperation programs depends on the partners involved, the extent of integration in the program and the subject of the cooperation. Differences in technological level could affect interoperability through differences in a range of sub-areas, including equipment, operational procedures and training level. For example, during *Operation Allied Force* in 1999, Norwegian F-16s mainly undertook Combat Air Patrol (CAP) missions as opposed to a full mission range, presumably because Norwegian F-16s at that time were not upgraded to fully comply with the NATO operational concept.

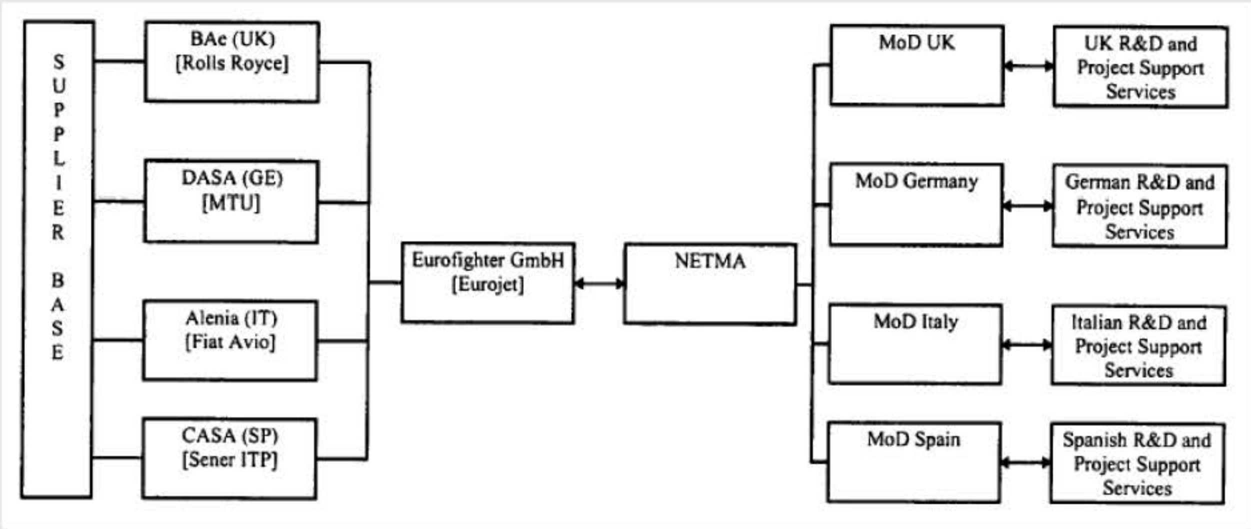
Even though differences in technological level can present a challenge, they can also be used to the programs' advantage if work-share is organized optimally according to the dissimilarities. In *International collaboration in research and development* [32], Mowery and Rosenberg state that in a collaboration of technological equals, an autonomous management structure is preferable, although this type of management can be costly. In collaboration programs involving a senior and a junior firm, on the other hand, financial and organizational structure appears to be less important as long as the technologically more advanced partner retains overall control.

Assuming Mowery and Rosenberg's observations for firms are valid for military cooperation between Nations, collaboration between equally technologically advanced countries should have a common autonomous management, which presumably would result in higher transaction costs. Collaboration between senior and junior military powers should be organized such that the senior power takes a larger responsibility, for instance as lead Nation or framework Nation. As a curious example, the development of the Eurofighter, a Type-I cooperation, could be categorized as a cooperation between technologically equal partners with overarching management both on the customer and supply side (see Fact Box). On the other hand, the development of the F-35, a Type-S cooperation where one Nation retains overall control, is led by the technologically first-tier Nation, the US, where Lockheed Martin is the managing authority on the supply side and the US F-35 Joint Program Office (JPO) manages the demand side.

Differences in technological level do not only impact the ability to work together, but also affect trust. Large differences could on one hand result in technologically less advanced partners fearing domination from other partners, and on the other hand, the more technological advanced partner could fear the junior partners have other incentives than cost efficiency, such as technology transfer.

Fact Box: Eurofighter Organization [33]

The Eurofighter program involves a large number of businesses interacting in a complex manner on both the supplier and the customer side. The former is organized in one multi-national agency for the aircraft (Eurofighter GmbH) and one for the engine (Eurojet), while the latter is organized under the NATO Eurofighter and Tornado Management Agency (NETMA).



4.2.3 Size

The size of a country will undoubtedly affect its image as a collaboration partner, militarily, politically and economically. Countries' relative geographical size, population, size and quality of armed forces, and economy are all characteristics that can be said to affect the relation between them. The idea is that distorted power structures in bilateral or multilateral arrangements can complicate the collaboration between the partners. It has been claimed that asymmetry in size raises fear of one side "dominating" the others and ignoring the smaller partners' needs [25]. On the other hand, larger Nations will often fear free riding behavior from the smaller partners [25]. Hence the relative size of Nations may have a significant impact on their ability to trust each other.

Differences in size between countries can be of importance for cooperation regardless of the level of trust between them, as countries of different size will face different challenges at different times and have differing incentives for engaging in cooperation. For instance, a difference in size can lead to differing operational requirements in armaments; smaller Nations face the critical mass problem long before their larger counterparts do; and, as will be seen in Chapter 5, the economic benefits can be different. Unaligned motives for joining cooperation could obviously in some circumstances pose a threat to its success.

4.2.4 Culture

Similar culture, i.e. similarity in the way of thinking and behavior, tends to ease collaboration, as the barriers created by lack of understanding are reduced and the ability to work together is enhanced. At the same time, similar culture enhances trust between collaborating partners. The closer the cooperation, the more important this factor is likely to be. The Norwegian, Swedish, Danish, Icelandic and Finnish defence cooperation (NORDEFCO) organization states that common traditions and culture are critical factors in the success of the Nordic defence cooperation [34]. Everything from differences in working hour arrangements, hierarchy in power structures, employment protection rights, the legal system, disposition to use force and the perceived value of a human life can affect the environment for cooperation. Cultural factors thus affect both trust and interoperability.

Fact Box: NORDEFCO Cooperation

The Norwegian, Swedish, Danish, Icelandic and Finnish defence cooperation (NORDEFCO) has a much broader focus than other collaboration initiatives in Europe. NORDEFCO aims to gain operational improvements and cost reductions from cooperating and integrating activities such as training, maintenance and logistics, in addition to cooperating on equipment acquisition.

NORDEFCO emphasizes that similarities in language, culture and traditions are important prerequisites for this collaboration. Geographical proximity is also important.

4.2.5 Historic Relations

Closely tied to cultural similarities are historic relations. A Nation's culture is strongly influenced by its history, as well as the course of history being affected by culture. However, culture and history can be considered separately as a Nation's culture is not uniquely determined by its history and vice versa. Common history is not necessarily equivalent to strong ties. In fact, a history of strained relations due to war and conflict can certainly constitute large obstacles for close defence cooperation.

Strong historic relations between Nations are key determinants for trust, but common history does not only affect the level of trust. Historical similarities can also lead to the development of common political and strategic interests between Nations, two factors that are highly relevant for their ability to closely cooperate [35]. For instance, a difference in regional focus (i.e. expeditionary mobile forces versus stationary national defence) is a factor that typically partly could be attributed to history. As with cultural similarity, the close historical ties between the Nordic countries are highlighted as success factors for the Nordic defence cooperation NORDEFCO [34].

4.2.6 Language and Communication

Well-functioning communication is imperative for closely integrated cooperation to be successful. A common language and understanding are thus important factors for the ability to cooperate. In order for communication to flow seamlessly, language barriers need to be minimized. It has been claimed that the Czechs and the Slovaks turned to each other for pooling and sharing in defence after budget cuts in 2010 partly because of similarities in language [25]. De Nijs [65] also points to communication and language barriers as some of the obstacles that can create friction and prevent organizations from fulfilling their tasks.

On the operational side there seems to be anecdotal evidence that infantry troops in enemy contact tend to switch to their mother tongue when the stress level rises, thus using the most familiar command language when the difference between life and death is at stake. In such situations, a common and familiar command language can be critical for the success of the tactical situation. For less time critical functions or when the anticipated levels of stress are lower, language barriers might play a smaller role.

Whether communication issues due to language barriers will be a deal breaker for cooperation or just result in an increase in transaction costs[2] depends on the interoperability required in the collaboration and the magnitude of the communication problems.

[2] The cost of making an economic exchange.

4.2.7 Implications for Cooperation Design

The potential costs involved in cooperating across international borders, described in Section 4.1, are potentially influenced by the degree to which the partners are similar or different. Transaction costs will likely increase when countries do not share a common history, language, culture or military ambition/ doctrine. This will be due to difficulties involved in working closely together and achieving interoperability, but might also arise from lack of trust and mutual understanding. Handing over parts of one Nation's armed forces to another sovereign state will in many cases constitute a great leap of faith. If that trust or understanding can be at least partially questioned, the governments involved might put into place costly control measures in order to reduce the perceived risks. Costs relating to this might then end up partly or completely offsetting the benefits from the cooperation effort.

Does this mean that countries should only work with the countries that are similar to them? No, it simply means that Nations will need to consider what to cooperate on and who to cooperate with. The intention of this chapter is to add some nuances to the understanding of international cooperation, not establish definite rules of thumb or do-and-don'ts of cooperation. Such rules of thumb will be of limited relevance, as trust and ability to work together are susceptible to change over time. In addition, the costs related to this diversity are also likely to change over time. Changing external conditions might lead governments to assess cooperation efforts radically differently. When changing budgets force Nations to remove whole capabilities from their defence structures, the risks involved in cooperating with another Nation might not seem like such show stoppers any longer. The risk-reducing and cost-increasing measures they would have otherwise contemplated are then likely perceived as less relevant.

So rather than only seeking cooperation with similar countries, the importance of the differences between Nations needs to be considered realistically. Such realistic and fact-based considerations will leave less room for speculation and lobbyism and will likely lead to more cooperation initiatives being implemented. The rest of this chapter will go into more detail about what the diversity in NATO means when a Nation is choosing the cooperation type and military level.

Through the study of past and present cooperation efforts, several factors have been singled out as important. In order to create a generic model that captures all these complex and interlocking factors, we here suggest summing these up to only two overarching factors. On one hand this is an oversimplification, on the other hand the generic model could be useful making top level assessments of possible future cooperation initiatives. Broadly speaking, the factors can be summed up as trust between the cooperating Nations and the ability to work together, or interoperability. The objective of this section is to identify how trust and interoperability play different roles depending on both cooperation form and military level. For some combinations of cooperation form and level, national attributes with respect to these parameters could be critical with the associated risk that the cooperation might not be efficient – hence not cost efficient.

The following discussion is organized around the three military levels defined in Chapter 2. Several country specific factors might be important at each level, but in general some will be more dominant than others. At the *branch* level, political and military trust is one of the main factors for successful cooperation. At the *capability* level, trust is undoubtedly important as well, and its importance probably rises with the dependency on capability in question for military success, on tactical, operational and strategic levels. It is also reasonable to assume political trust will become increasingly important for strategic capabilities, whereas military trust becomes more important at the tactical level.

At the *capability* level, the ability to integrate the asset in question into an operating force also becomes important. In general, interoperability tends to be more easily accomplished at the *strategic* level and becomes more difficult at the *tactical* level, which is characterized by high tempo and communication requirements. Interoperability also seems more readily accomplished with air and sea units compared to land units.

At the *support* level, trust is important in the sense that partners are assured they receive what they pay for, i.e. security of supply. However, the vast areas of potential cooperation probably make it impossible to highlight just a few factors. Depending on cooperation area and type, the full spectrum of factors described in in this chapter could be applicable. Figure 4-2 summarizes the general factors this report believes to be important at each level, and serves as a guide to the elaboration on each level in this section.

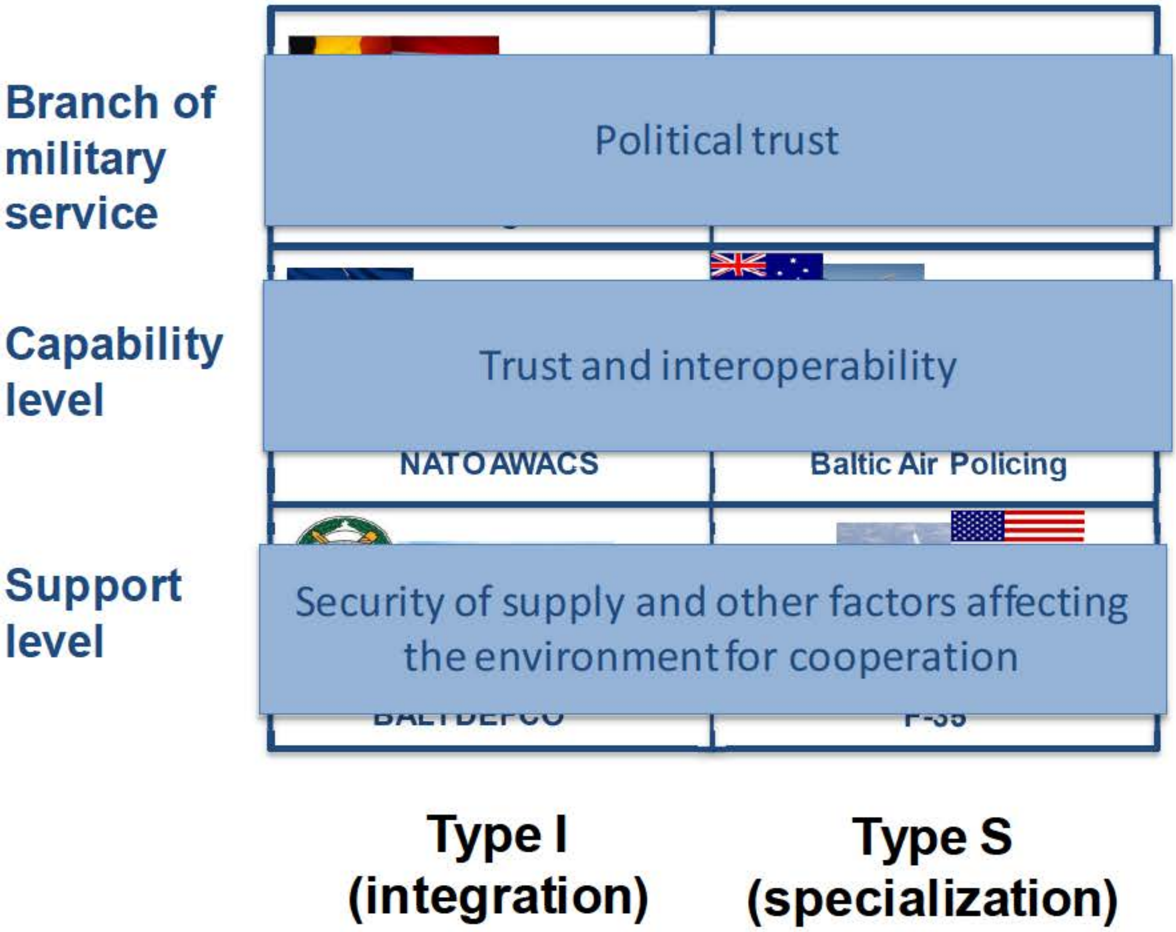


Figure 4-2: Main Factors Affecting Cooperation at Different Levels.

4.2.8 Branch of Military Services Level

At the highest military level, one Nation's access to and use of military force depends completely on the others', implying a corresponding high level of political trust and integration. For instance, two cooperating Nations with highly integrated military services, i.e. through a Type-I cooperation arrangement, will not be able to deploy forces to a conflict zone if both Nations are not committed. The same holds partly true if they are organized according to a cooperation of Type-S, as each Nation clearly could deploy the forces they possess and have specialized in, but not the full capability spectrum. Hence, in order for a cooperation initiative at this level to be successful, the partner Nations need not only to have the same military ambitions, but also need to have aligned political disposition to deploy forces.

In addition, there should be a mutual confidence and trust that military assistance will be provided in a timely manner and according to national preferences and doctrine. The importance of this requirement could be toned down for crisis management by organizing the cooperation as Type-I, with some purely national task groups for selected prioritized mission types. Still, for high-intensity conflict scenarios integration at the

branch level is a large step for most Nations to undertake, and probably unrealistic in the near future. However, cultural and historical commonality among the Nations as well as long traditions for cooperation at the lower levels can spur cooperation at the branch level in the future.

Because close cooperation at this level requires substantial national sovereignty to be given up, Type-I cooperation may be easier to implement than Type-S, as national control over a broader spectrum of activities may be maintained.

4.2.9 Capability Level

Cooperation at the capability level requires a high degree of trust. However, compared to the branch level, the scope of cooperation could be limited by cooperative arrangements only for selected platforms – for which the level of trust is perceived as acceptable. Cooperation on platforms considered to be of strategic importance or deemed necessary to retain ability for crisis management could require more trust than for supportive systems. For instance, it would signal greater trust to rely on partners to provide the capability of a destroyer compared to the supply ship accompanying it. Therefore cooperation at this level probably should start with supportive capabilities that are deemed less critical.

Cooperation at the capability level implies some loss of national sovereignty and control, which is associated with some risk. This was clearly demonstrated during Operation Unified Protector in Libya in 2012, when Nations opposing the operation withdrew military capabilities and personnel from commonly owned NATO assets like the AWACS [31]. The potential loss is larger for Type-S arrangements which force the non-specialized partners to place trust in their Allied partners, than for Type-I arrangements which can be designed in a way to secure some national capacity in the event of disagreement. Therefore, critical and strategically important systems are probably more suited for Type-I cooperation, whereas both types could work for supportive platforms deemed less critical. In order to build confidence and trust, Type-I could be a starting point also for supportive systems, which then can spur Type-S cooperation at later stages, since the latter cooperation form has the largest economic potential (see Chapter 3).

Military capabilities must be integrated in the command and control chain as well as trained regularly with the units they support in order to achieve the synergy often referred to as the *combined arms effect* in military operations. Generally, the more tactical and operational platforms and systems, those that may be used in a high-tempo combat environment, require higher peacetime integration for interoperability [28]. The opposite in general holds true for systems of a more supportive character that are also less critical for operations. There also seems to be evidence from practice that multi-national interoperability in general is easiest for naval forces and most difficult for land forces [28]. This suggests that Type-I cooperation could be necessary for those systems operating in a high-tempo combat environment, whereas both types of cooperation could be suited for supportive systems. Also, air and sea platforms could be better candidates for cooperation than land systems.

In order to make Type-I cooperation work at the capability level, military personnel need to work closely, as military operations include complex command and control, with a multitude of interacting units. At the lower military command levels, the ability to work together (interoperability) becomes increasingly difficult [28]. Also, decision-making at the tactical level tends to be more time-critical than at the strategic and operational levels. Whether or not conditions are met for Type-I cooperation depends on factors such as language barriers, culture, technological level and trust among the military personnel involved. For capabilities that require a high degree of interoperability, the depth of force integration among the cooperating Nations probably should be balanced against differences in the country specifics. At some level of differences between cooperating countries, the cost of integration probably outweighs the benefits.

To summarize, if the capability in question is easily integrated in the collaborating Nations' armed forces and there is sufficient political trust, Type-S should hold the larger economic potential as this avoids duplication of efforts and allows countries to benefit from economies of scale, scope and learning effects (Chapter 3).

This cooperation form is probably most easily obtained with supporting units. Type-I could be chosen if the level of trust is not sufficient for Type-S, as some national sovereignty could then be retained, which probably would be a requirement for strategic and critical capabilities. Those capabilities also often require peacetime training and strong ties to the force they support, hence Type-I is the preferred cooperation form. However, the level of integration should be carefully balanced against conditions determined by factors such as language barriers, culture and technological level, to maximize cost efficiency. Type-I cooperation could be arranged with varying degrees of integration – even allowing Nations to maintain control over key personnel and platforms, thus maintaining sovereignty in selected areas. This is illustrated in Case Study #3 in Chapter 5.

For NATO, the capability level presents great potential for closer cooperation, but also requires strong relations between the collaborating Nations. Although the required level of trust can be somewhat lower here than for the branch level, the need for interoperability can be even higher. Systems that are critical for operations such as strategic platforms, in general require a high level of interoperability. For these, Type-I cooperation could be best suited. Type-S probably has greater chance of success for platforms that are of more supportive character. Nations starting their cooperation at this level should begin with Type-I cooperation on supportive systems, and gradually move towards Type-S which holds greater economic potential, as their confidence in each other strengthens over time.

4.2.10 Support Level

Support activities such as logistics, training, education, maintenance, research, development and production generally tend to be of less strategic character and less critical to operations compared to combat systems. Decision-making also happens on a slower timescale. This is especially the case for peacetime activities, whereas certain types of field support, such as combat service support and electronic support (electronic warfare) could be viewed as more operational. By the same arguments as under Section 3.1, Type-S should hold the larger economic potential and be suited for functions of supportive character. As the support level in general is less involved in operations than the capability level, Type-S is a more relevant and potentially successful cooperation type for the support level.

Interoperability for peacetime support activities implies some degree of harmonized equipment, procedures and training standards. There are for instance numerous examples of maintenance and training initiatives in the Alliance for Nations having the same platform. With long lead times in several areas and delivery according to prearranged standards, many support activities are neither time critical nor require extensive integration and training. For these activities Type-S specialization should hold greater potential due to scale advantages. Typical examples of Type-S cooperation include maintenance and specialist training, the latter covered in Case Study #2 in Chapter 5.

Activities that tend to be time critical, require training within the organization they support, or where difficult cross priorities arise that jeopardize security of supply could benefit from a Type-I cooperation. For instance, if two Nations cooperate on medevac in an operation and a prioritization dilemma occurs, the trust between partners could be affected if one Nation feels its soldiers take second place.

Cooperation at the support level requires less political integration (trust) when the chances that operations could be jeopardized by discontinuance of the function are smaller. Functions such as acquisition of equipment and military training are less likely to affect ongoing operations. Maintenance activities could jeopardize security of supply in certain situations, and logistics operations in theatre could be deemed critical.

In-theatre supply is probably more a concern related to military integration than political trust. The guarantee of military assistance could be perceived to be more secure when provided by a multi-national organization compared to the reliance on a single Nation. Therefore, when security of supply is a concern, Type-I should

be preferred. In special cases, arrangements where full control is retained for key capabilities could be considered.

In general, at the support level Type-S cooperation has more potential than Type-I cooperation. The need for political and military trust and interoperability is smaller here and the economic benefits from specialization can be substantial. Exceptions to this are support activities that are more time critical, require joint training or where cross priorities can arise that jeopardize security of supply. Such cases highlight the need for a high level of trust and interoperability.

4.3 OPERATIONAL AND POLITICAL COSTS

4.3.1 Operational Costs of Defence Cooperation

The most obvious operational disadvantage of international defence cooperation is the fact that national preferences will, to some degree, be neglected. Both timelines and capability requirements will differ between countries, and the decision to join forces in the acquisition of new generations of military equipment means that Nations have to compromise [48]. A consequence might be that the procurement is delayed or forced on according to the preferred timeline of one of the partner Nations. Another result can be that countries have to accept procuring more complex systems than those they actually need, with consequently higher costs, or that capability requirements of a country are ignored in order to satisfy all partner Nations. This issue is not just an acquisition problem; the problem of differing demands can also arise when conducting cooperation on other support level activities, such as training. The need for alignment of requirements can be of even greater importance when cooperating at a higher level, such as the common operation of a military system.

Cooperating on defence will, for many Nations, imply that parts of the development and production are no longer a national responsibility, but instead is either outsourced to a collaborating partner or undertaken jointly through some sort of work-share agreement.

Fact Box: The Nordic Viking Submarine Project

The Nordic Viking Submarine cooperation was initiated in the mid-1990s with the intention of harmonizing operational requirements, budgetary plans and delivery schedules for the next submarine generation of the three Nordic countries, Sweden, Norway and Denmark. Finland played a minor role as an observer in the project. The Viking Submarine Corporation was established as a prime contractor for the program, as a result of a joint venture agreement between Kockum (Sweden), Kongsberg Defence and Aerospace (Norway) and Odense Steel Shipyard (Denmark), with the Joint Project Office being established in 1997.

It was recognized from the beginning that the requirements of the three Nations would differ. The geographical conditions of Norway result in a need for an ocean-going submarine with greater range than that of the Swedes and Danes, who require a vessel mainly for coastal operations in the Baltic Sea.
It was still considered feasible to be able to come up with a common solution through compromise. However, combined with tightened defence budgets, the diverging requirements of the three countries led to the project being abandoned about ten years after it was initiated.

In cooperation efforts of Type-S in particular, national military expertise can be eroded over time as the specialized production is taking place in a different country. This loss of essential competence can be seen as a large disadvantage of cooperation, as the Norwegian Ministry of Defence describes in the report *The National Defence and the Norwegian Defence Industry – Strategic Partners* [49]. The operational cost of losing important technological and military competence nationally can be seen as being too large to be outweighed by the economic gains, especially in areas where the economic gains from cooperation are smaller in real terms, such as for the procurement of less expensive systems.

As mentioned previously, one consequence of procuring together is the standardization of equipment within the group of collaborating Nations. Although standardized equipment is viewed as a largely advantageous consequence, the fact that a group of countries is equipped with exactly the same system can also be seen as an operational weakness as this standardization can ease the enemy's process of adapting, making the Alliance more vulnerable in military operations [50].

Cooperation on the acquisition of military equipment can also have other negative operational implications. In cases where cooperation implies the joint production and development of equipment in order to derive economies of scale and learning curve effects, one negative side effect can be the generation of monopoly power for the chosen supplier. The economic cost of this is described in more detail earlier in this chapter, but this issue can also have negative consequences from an operational point of view. In a market characterized by a monopoly supplier, the choices of the buyers are limited to the products of that one producer. A limited number of possibilities and choices of military goods and services are considered to negatively affect the military capability of a Nation and NATO as a whole.

Collaboration in other areas, on the support level, capability level or branch level can lead to other operational costs. Both Type-I cooperation programs and Type-S cooperation programs will in most cases lead to some national independence being lost. Reduced flexibility in planning and execution of operations is another significant disadvantage of close cooperation, especially at the higher levels.

In order to reap the largest cost efficiency gains from cooperation, there needs to be some sort of specialization in tasks, such as in a Type-S cooperation arrangement. However, leaving the responsibility of, for example, support services, such as maintenance of fighter jets, to a partner Nation in order to gain economies of scale, generates dependencies. In a Type-I cooperation, the potential for cost savings is less than in a Type-S cooperation but at the same time some national control over the production process is kept.

The economic gains from entering a cooperation program will always have to be weighed against the operational disadvantages as well as the political costs, discussed below.

4.3.2 Political Costs of Defence Cooperation

Depending on the scope of the collaboration, there will also be political disadvantages from giving up national sovereignty and joining international defence cooperation. Although perhaps the most severe disadvantages are the security policy implications, the industrial policy implications can be just as important and prevent the successful implementation of cooperation. The following two sections summarize the potential drawbacks of cooperation in terms of security and industrial policy implications.

4.3.2.1 Security Policy Costs

As mentioned previously, close cooperation will lead to some of the national freedom of action being lost. This is not just an operational cost; it can also have large political implications. Defence cooperation at the capability level or the branch level could mean that a country must engage in operations, agreements, etc., that they otherwise would not choose to engage in. Similarly, a country may have to refrain from engaging in activities that it would otherwise choose to engage in. Collaborative programs may even be used as a means for stronger Nations to influence the defence capabilities and strategies of weaker partners [26].

Darnis et al. [3] claim that cooperative programs can help maintain the defence industrial and technological base within the cooperating Alliance, and help ensure security of supply. However, cooperation in the most cost efficient way, a way that reduces duplication of efforts, implies co-locating production. This means that some production must be moved out of the national borders. This can feel, rightfully or not, as though the national security of supply of those goods and services has decreased. This issue will be more pronounced the lower the level of trust between the collaborating countries.

If the collaboration program implies joint production, some countries will consider the sharing of sensitive national military technology as a large cost, making production outside of cooperation the chosen option [46]. This issue will be of greater concern the higher the strategic importance of the defence good or service in question. Choosing partners with a history of strong national relations and sufficient levels of trust will reduce the cost.

Ultimately, failed collaboration programs can result in worsened international relations and for this reason the political costs represent significant hurdles when initiating new collaboration programs.

4.3.2.2 Industrial Policy Costs

Arguments often heard against defence cooperation, especially Type-S *Specialization* cooperation arrangements, emphasize the operational and security policy factors, such as the importance of security of supply, the need to maintain national competence in certain areas and the fact that Nations differ in their requirements and time schedule. Behind those arguments, often not declared, lies the wish to strengthen the national defence industrial base, protect employment, uphold marginalized local communities and other national political considerations not directly linked to the national defence capacity.

Cooperation projects, in order to gain economic savings, imply reducing duplication of efforts. In order to achieve the largest cost savings, production must be co-located. For the areas where production is downscaled following this process, the loss of employment and the negative effect this can have on already marginalized local communities can easily be seen to outweigh the efficiency gains. Governments are often also unwilling to spend domestic tax revenues on goods produced abroad [51].

Fact Box: L-159 Advanced Light Combat Aircraft (ALCA)[3]

The L-159 ALCA was developed and produced by the Czech avionics company Aero Vodochody with a team of non-Czech companies including Boeing and Honeywell. Aero Vodochody was at the time owned 50 percent by the Czech government and 35 percent by the US company Boeing. The first 73 L-159 aircraft where delivered to the Czech Air Force by the end of 2003.

Despite the large number of aircraft on the international market meeting the required specifications, it was decided to launch development, production and delivery of the aircraft for the Czech Air Force. The reason was partly to protect the national air defence industry and to give to national industry an opportunity to enhance competitiveness by keeping a high level technological base. Another reason was to keep employment in the region of the company.

At the same time there was a lack of clear specification of operational needs from the Czech Air Force. The technical specifications delivered by the user were not based on conclusions stemming from

[3] For further information on the Czech key lessons learned from the ALCA L-159 cooperation, see Annex C.

comprehensive military capability analysis reflecting operational requirements, and there was no pragmatic specification identifying the number of aircraft required to meet the country's military ambitions.

The opportunity to trade the L-159 on the international defence market is quite limited due to relatively stiff competition. In addition, due to the high-tech defence standard avionics delivered by the US's Boeing, there is the need to ask the US government for authorization every time the aircraft might become a subject of foreign sale. These factors have severely limited the possibilities of exporting the aircraft.

The L-159 ALCA example illustrates how benefits in some areas can be followed by disadvantages in other areas. In order to strengthen the national avionics industry and local communities, the Czech Republic ended up with an aircraft that did not meet their operational requirements and was difficult to export and resell.

In addition to the potential increase in transaction costs from organizing production as Type-I *Integration* cooperation, there are other disadvantages that may result from this form of arrangement. The more closely integrated the production processes, the more time and resources can be expected to be needed in order to sort out difficulties linked to the bureaucracy of patents, national standards, laws and regulations etc. [52]. Other disadvantages can be the unintentional transfer of technology that may harm more advanced industries in countries with a high-tech defence industry [26]. The need for sharing new national technological developments through cooperation can be seen as a cost by some Nations, though less technologically developed Nations can consider it a gain. The time spent bringing the lower-tech country up to speed in order for two partner Nations to co-produce can also be a large efficiency loss for countries with highly developed defence technology.

Chapter 5 – QUANTITATIVE ANALYSIS: CASE STUDIES

In order to quantify the potential benefits and costs related to international cooperation, the SAS-090 technical team set out to perform a quantitative analysis. Due to the lack of available data on previous cooperation efforts, the need to compare different types and levels of cooperation and the releasability of costing data, it was decided to establish a case study based on the hypothetical NATO Fighter (NF). The aim of this chapter is thus to quantify the potential savings or operational benefits of cooperation in different contexts in order to derive an approximation of the order of magnitude of potential benefits.

The NF cost structure is based on historical cost data for other fighter aircrafts. The technological level, production costs and operation costs are based on other fighter aircraft being developed and produced today, but they do not represent a specific aircraft. An estimate of the acquisition cost for the NF was derived using the standard cost per ton estimates collected by Pugh [13] over 30 years and applied to the weight of the latest fighter aircraft designs. The full life-cycle costs of the NF, broken down by cost categories such as maintenance, training or infrastructure, were adapted from the Canadian Strategic Cost Model (SCM) [20]. The SCM represents the detailed cost breakdown of the fighter aircraft capability in Canada and was used as a guideline for creating a realistic cost breakdown structure for the NF. A more detailed description of the model is provided in Annex B.

In addition to the NF cost estimates, operational benefits were also assessed with the help of the Norwegian FLYT2 model [21], [22], [61]. The FLYT2 model is used to calculate a mission capable rate under different constraints related to the number of aircraft, maintenance personnel and the flight schedule. A more detailed description of the FLYT2 model is provided in Annex A.

The quantitative analysis of the NATO fighter is structured into three different cases. The three case studies examine the development and acquisition of the NF, the education and training of the NF pilots and the operation of the NF in the context of an alliance. The different scenarios within each case study explore different types of cooperation requiring different levels of integration (Figure 5-1). The analysis of cooperation at the 'service' level as well as the analysis of Type-S cooperation at the 'capability' level are left out of the case studies. These particular arrangements are considered to be less relevant and less likely to be used in the years to come in NATO.

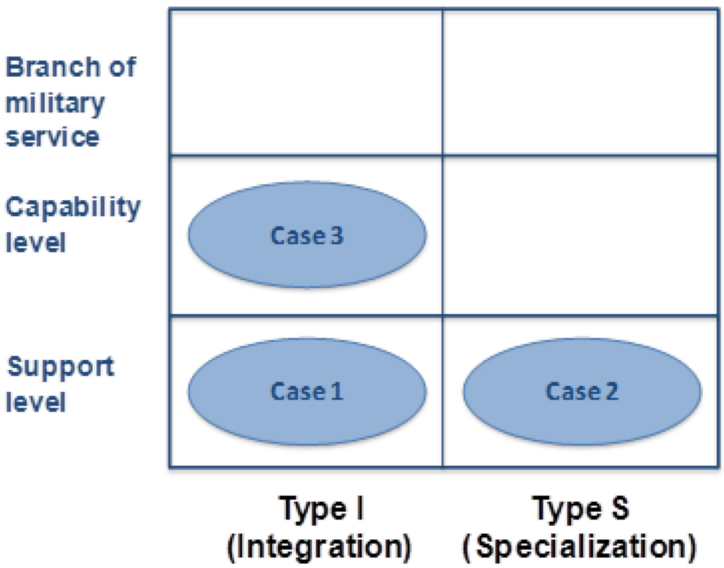


Figure 5-1: Case Studies on the Spectrum of Cooperation.

While the case studies are based on a specific capability, the observations are applicable to a whole range of military capabilities. As will be discussed later, similar observations could be made for most systems with a high ratio of fixed to variable costs.

5.1 CASE STUDY #1 – COMMON DEVELOPMENT AND ACQUISITION

5.1.1 Context

With declining budgets and the cost of fighter aircraft increasing at a rate of, on average, 4 percent above inflation [13], the defence departments' purchasing power is quickly decreasing. This means that the budget necessary to purchase 100 planes today would only afford the replacement of 39 aircraft in 2035. In order to retain the fighter aircraft fleet without increasing the defence budgets, Nations will either have to increase the share of the defence budget allocated to the purchase of fighter aircraft (at the expense of other capabilities) or find cost saving measures such as cooperation.

In the first option, if the funds redirected to the fighter's acquisition are taken from the fighter aircraft capability budget, the capital cost would grow to represent a much larger share of the capability budget (from 17 percent in 2011 to 44 percent in 2035 in our model). This would imply a proportional decrease in funding of the order of 35 percent for the operations and maintenance, infrastructure, support, research and development and training costs associated with the fighter aircraft (see Figure 5-2).

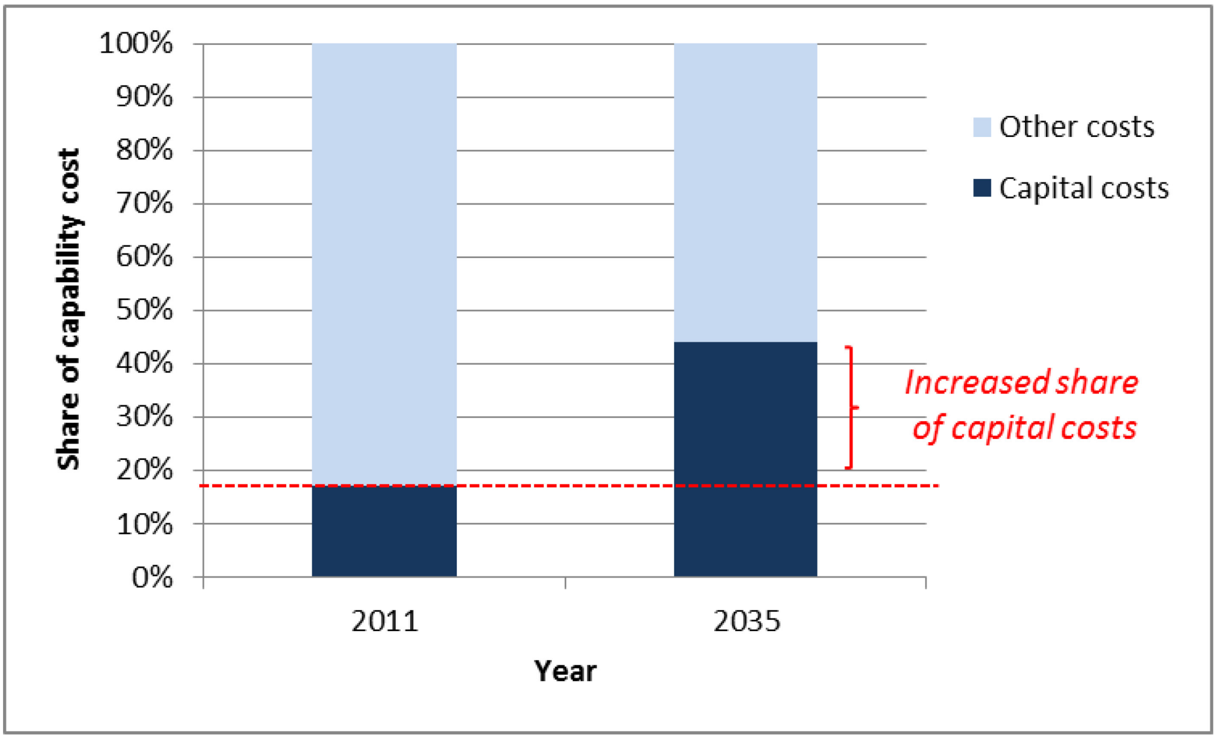


Figure 5-2: Share of the Fighter Aircraft Capability Dedicated to Capital Acquisition versus Other Costs. It is assumed that the total number of aircraft and life-cycle costs in real terms is constant, and as a consequence of unit cost growth, the capital cost-share increases between 2011 and 2035.

For a military the size of Canada, the fighter capability represents approximately 10 percent of the defence budget. This means that the capital cost related to the fighter acquisition could grow from representing 1.7 percent of the total yearly defence budget to a share of 4.4 percent. This amount is significant when considering that the same type of analysis can be applied to all military systems. Absorbing this level of cost

increase in the defence budget can be especially difficult for smaller Nations where the fighter capability already represents a large share of the smaller defence budget.

Without increasing defence budgets, NATO Nations face a decrease in units as a result of the loss of purchasing power associated with the defence specific inflation of fighter aircraft. The following scenarios attempt to estimate the potential economic gains from cooperation on the development and acquisition of the aircraft and to determine whether these gains could compensate for the loss of purchasing power.

5.1.2 Scenario 1: Nations as Sole Developers

As a baseline scenario, the cost of the development and the acquisition of an NF-like fighter aircraft in 2011 is estimated when each Nation develops its own aircraft, taking responsibility for all development costs.

In this scenario, Country 1 would have a total fleet cost C_1 expressed as:

$$C_1 = D + UC \times n_1 \,,$$

where D is the development cost (non-recurring), UC the recurring unit cost and n_1 the number of aircraft acquired by Country 1. In this baseline scenario, all countries develop their own capability, multiplying the total cost of development by the number of countries developing a fighter aircraft equivalent to the NF. This is of course far from optimal when considering the price paid for the capability by the group of countries. The development cost will also constitute a large burden on countries requiring a smaller fleet since the fixed costs are distributed on a smaller number of units. Figure 5-3 shows the estimated total unit cost, including development, as a function of the fleet size, assuming, as above, that the non-recurring unit cost is USD 189 million and assuming that the development is priced at 100 times the unit cost, or USD 18.9 billion[1].

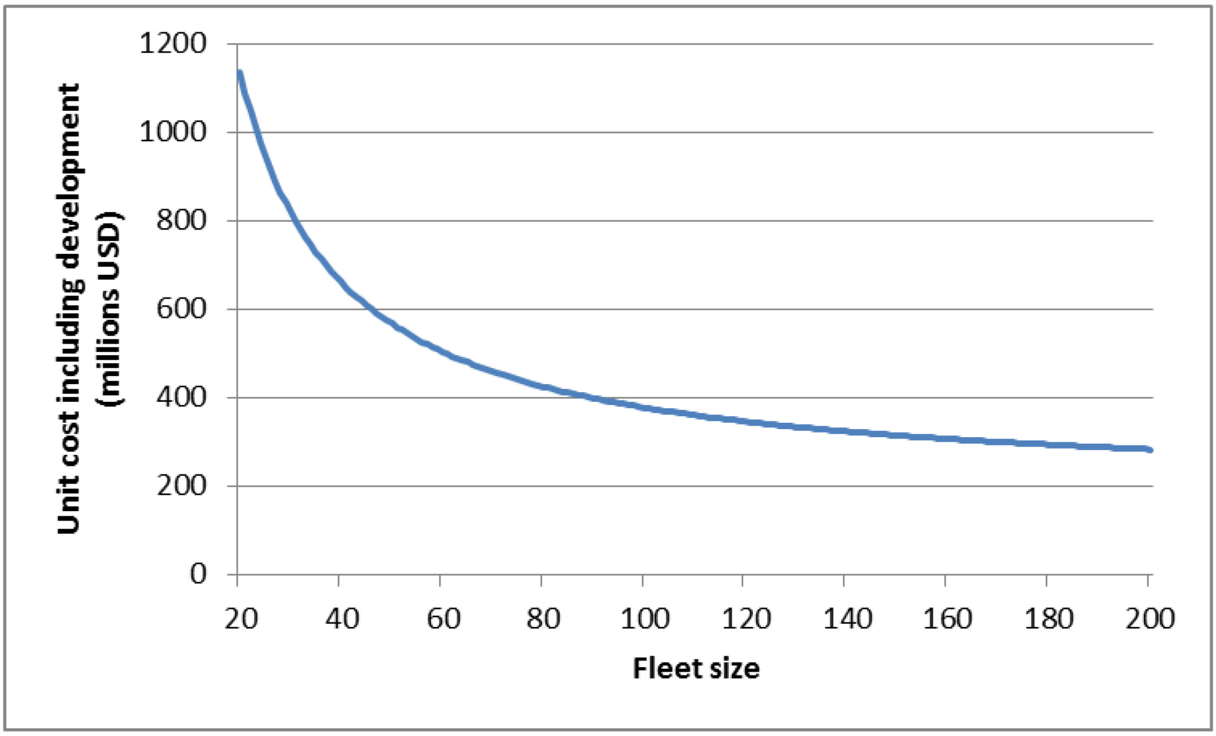


Figure 5-3: NF Total Unit Cost for Different Fleet Sizes in the Baseline Scenario.

[1] Based on Pugh's rule of thumb (see [13]).

If the development was conducted in a single country, with other Nations agreeing to purchase the fully developed aircraft, the cost to the group of Nations would be much smaller. While this arrangement is economical to the group of Nations as a whole, there may not be a country willing to take on 100 percent of the development costs. Also, the other countries may not be willing to hand over all the development to another country. The following section looks at the cost of the NF fleets in a shared development and acquisition scenario.

5.1.3 Scenario 2: Consortium Development

In a consortium scenario, all participating countries could agree to contribute to the development cost proportionately to the size of the fleet that they are acquiring, as was the case for the development of the Eurofighter. This represents a generalization of the situation where one country acts as a lead developer, such as the arrangement for the acquisition of the F-35 jets. However, in the consortium scenario, there is no lead developer and the country acquiring the largest fleet will end up assuming the largest share of the development costs. The cost for a country i ($i = 1,\ldots,N$) to acquire n_i planes can be expressed by:

$$C_i = \frac{n_i}{\sum_{k=1}^{N} n_k} \times D + UC \times n_i.$$

To compare this cooperation scenario to the baseline scenario, the simple case of an alliance of 5 countries acquiring respectively 120, 90, 70, 40 and 10 NF aircraft is considered. These numbers of aircraft are meant to represent numbers typically found in medium- and small-sized NATO Nations.[2] It is emphasized that the principles for savings shown for this case are not unique for fighter aircraft, but applicable for a range of development and acquisition programs sharing the same cost structure – with high fixed costs and learning effects as described in Chapter 3.

Table 5-1 and Figure 5-4 show the total unit cost of the aircraft (including development) for each of the countries in the Alliance in a scenario where all Nations develop their own aircraft and in a consortium scenario.

Table 5-1: Total Unit Cost for Each Country in Two Scenarios (in Millions of USD).

	Fleet Size	Unit Cost (Million USD)		Savings (%)
		Nations as Sole Developers	Consortium Development	
Country A	120	347	246	29
Country B	90	399	246	38
Country C	70	459	246	46
Country D	40	661	246	63
Country E	10	2,079	246	88
Average		475	246	48

[2] In order to put these numbers into perspective, one could look at inventories or planned acquisitions of jet fighters. For instance, current procurement plans for F-35 are: 138 for the UK, 100 for Turkey and Australia, 85 for the Netherlands, 65 for Canada, 60 for Italy, 42 for Japan and 39 for Denmark (Wikipedia: http://en.wikipedia.org/wiki/Lockheed_Martin_F-35_Lightning_II_procurement (accessed July 2013)). The Czech Republic represents a small nation, leasing 12 JAS-39C for operational purposes (Wikipedia: http://en.wikipedia.org/wiki/Czech_Air_force (visited July 2013)).

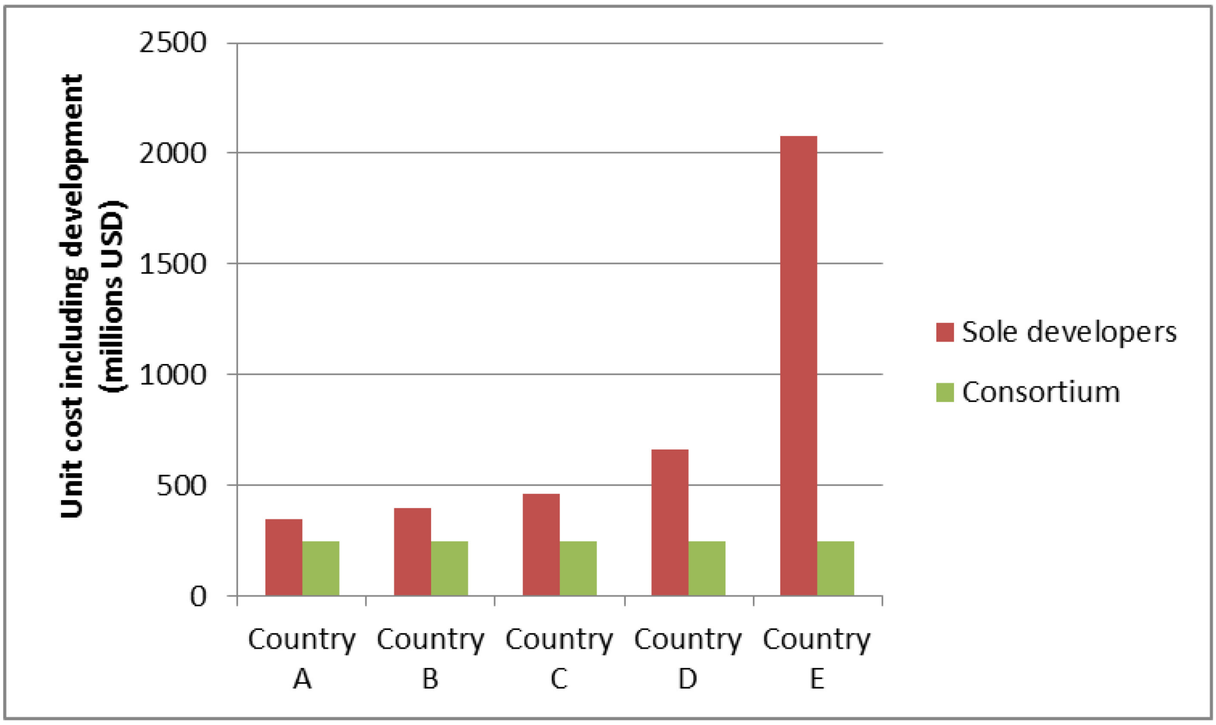


Figure 5-4: Total Unit Cost for Each Country in Two Scenarios (in Millions of USD).

Table 5-2 and Figure 5-5 show the fleet cost for each of the countries in the same scenarios.

Table 5-2: Fleet Cost for Each Country in the Different Cooperation Scenarios (in Millions of USD).

	Fleet Size	Fleet Cost (Million USD)		Savings (%)
		Nations as Sole Developers	Consortium Development	
Country A	120	41,580	29,553	29
Country B	90	35,910	22,165	38
Country C	70	32,130	17,239	46
Country D	40	26,460	9,851	63
Country E	10	20,790	2,462	88
Total		156,870	81,270	48

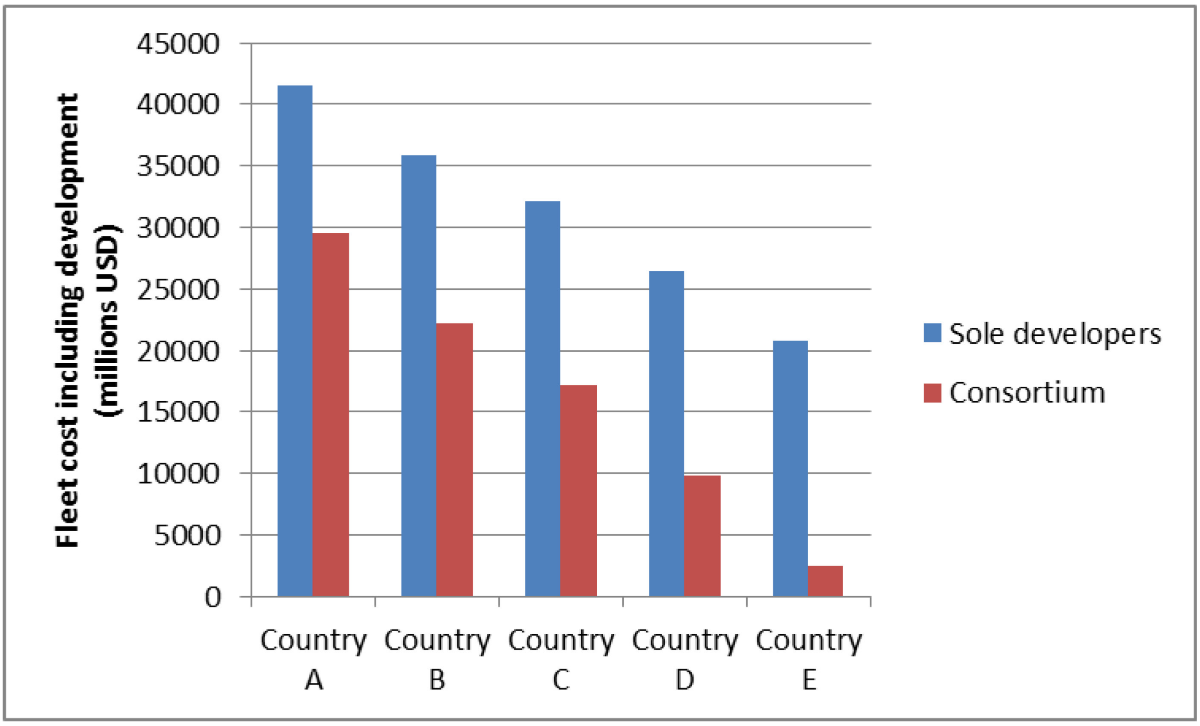


Figure 5-5: Fleet Cost for Each Country in the Different Cooperation Scenarios (in Millions of USD).

Overall, collaboration on the development and acquisition of the NF fighter aircraft cuts the total cost of the fighter procurement for the Alliance by almost half. It is clear from Figure 5-4 and Figure 5-5 that the countries acquiring smaller fleets stand to benefit the most from cooperation in development and acquisition. For Country E in our example, the participation in a consortium reduces the final price tag of the aircraft by almost 10 times. Although it is unlikely that the smaller Nations would develop their own high capacity combat aircraft as an alternative to cooperation, medium-sized France and Sweden have demonstrated both the will and capacity in doing so by producing Rafale and Gripen respectively. Likewise, smaller Nations can opt for less capable jet trainers, as illustrated by the L-159 example described in Annex C and pointed out as a duplicated capability in Figure 1-2.

The savings observed are a result of the redistribution of the fixed costs on a larger number of units. For this reason, the savings from cooperation with more countries or for an increased number of aircraft should lead to additional savings. However, this relation is not straightforward, as increased production volumes can lead both to additional savings, as workers become more knowledgeable, and additional costs, as the requirements of different stakeholders must be accommodated. The following sections examine some of the factors that affect the potential savings from cooperation related to the development and acquisition of equipment.

5.1.4 Economies of Scale and Learning Effects

By acquiring the same equipment, groups of Nations can benefit from lower unit costs by redistributing the fixed development cost over a larger number of units. However, additional benefits can be achieved, since the longer production runs also led to learning effects as workers become more knowledgeable and efficient at their job.

The shape and scale of the learning curve depends greatly on the type of production process (for instance the ratio of hand vs. machine labor). Wright [62], [63] proposed a learning curve equation for aircraft production which is still in use today. The relation is as follows:

$$C(Q) = A_1 \times Q^b,$$

where *C(Q)* is the average unit cost of the Q^{th} unit produced and A_1 is the cost of the first unit produced. The factor b represents a learning ratio which can be expressed as the natural log of the learning slope over the natural log of 2. The only way to determine the precise learning slope and value of b for a production process is to rely on production data. However, there are 'rules of thumb' and guidelines for estimating the learning slope in different industrial sectors. The Cost Estimator's Reference Manual [67] quotes a learning slope of 85 percent in the aerospace industry. The interpretation of the 85 percent learning slope is that when the quantity produced doubles, the resources required to produce one unit are reduced by 15 percent. These guidelines are in line with the estimates quoted in a RAND study on the factors affecting cost growth for fixed-wing aircraft [12] and the 2008 NASA Cost Estimating Handbook [64].

Figure 5-6 illustrates the impact of 85 percent and 95 percent Learning Slopes (LS) on the production of the NF fighter aircraft based on the assumption that the first unit produced costs USD 189 million[3] in recurring costs.

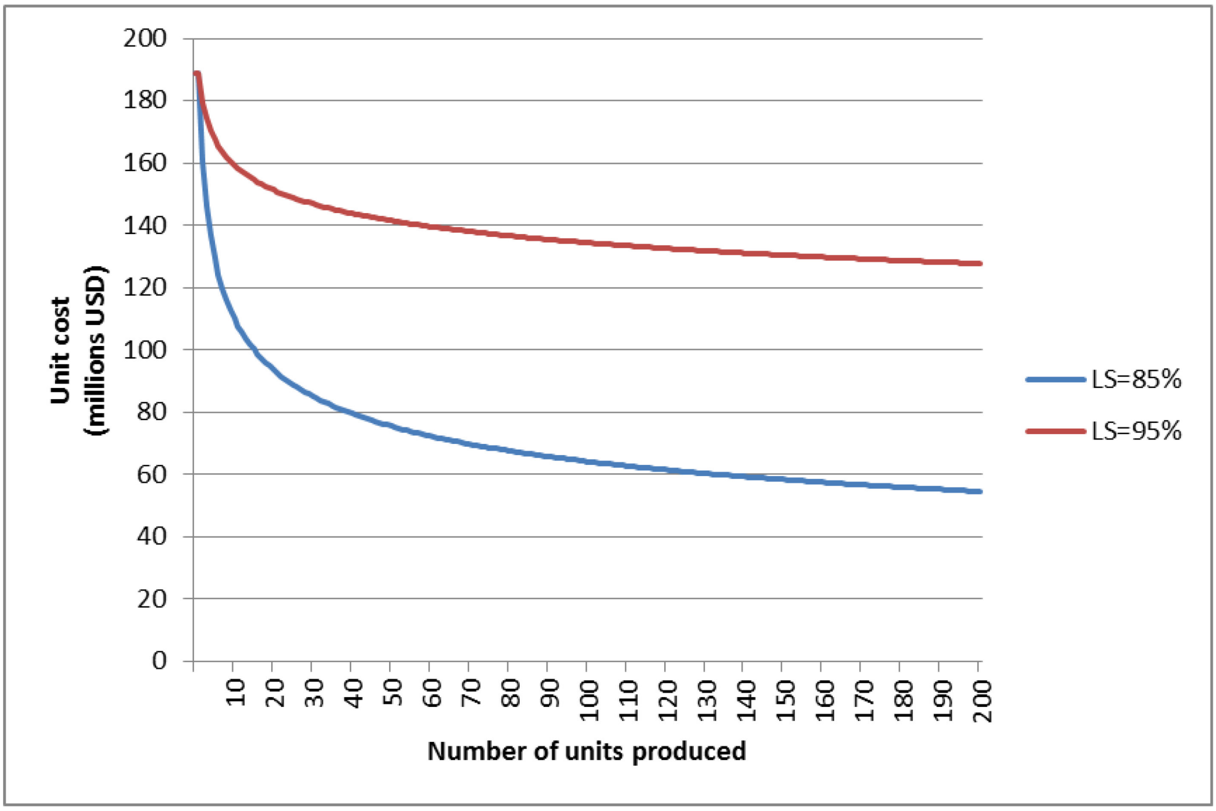


Figure 5-6: Impact of Learning Factors on Recurring Unit Cost.

For the example group of countries defined previously, a learning slope of 85 percent sustained for the whole production cycle leads to reductions of approximately 52 percent on the price paid by each country for their fleet of NFs in a consortium scenario. A possibly more realistic learning slope of 95 percent leads to reduction in fleet cost of approximately 23 percent.

[3] This cost estimate from [13] refers to an estimate of production cost per unit, excluding development costs. Our assumption of this being the first unit produced have no bearing on our estimates of percent savings in the case studies, but is sensitive for the estimates of absolute USD-savings in the cases.

It should be noted that the learning effects will vary from one system to another and from one project to the next. The design of the cooperation can also affect the learning curve, for instance, when production facilities are duplicated. Finally, changes to the aircraft design during the production, whether planned or not, can completely erase the economic benefits from learning effects (this is discussed in more detail in [12]). Despite these constraints, the simple example presented here shows that the potential for savings from learning effects can be significant when looking at the purchase of fighter aircraft and that measures taken to improve the learning rate, even slightly, can lead to significant benefits.

Some factors with the potential to reduce the savings achieved from learning effects are discussed in the following section.

5.1.5 Transaction Costs

As has been shown above, the pooling of acquisitions can lead to significant cost savings for countries purchasing both small and large numbers of aircraft. However, with the process of cooperation comes a number of additional costs such as those associated with additional administration, meetings and delays. It has been suggested that as a rule of thumb, the cost of a collaborative project is increased by the square root of the number of participants in the project (see Section 4.1.4). In other words, the cost of the development of the NF involving N countries becomes: $D \times \sqrt{N}$. It is a strong simplification to use such a rule-of-thumb, and the transaction costs could be lower as well as higher, depending on organization and management of the cooperation. Nevertheless, this rule is used here to visualize the transaction costs of cooperation which can be substantial in some cases.

Figure 5-7 shows the growth of the development costs as a function of the number of partners in the cooperation in the case of the NF fighter aircraft, with the same assumptions as above.

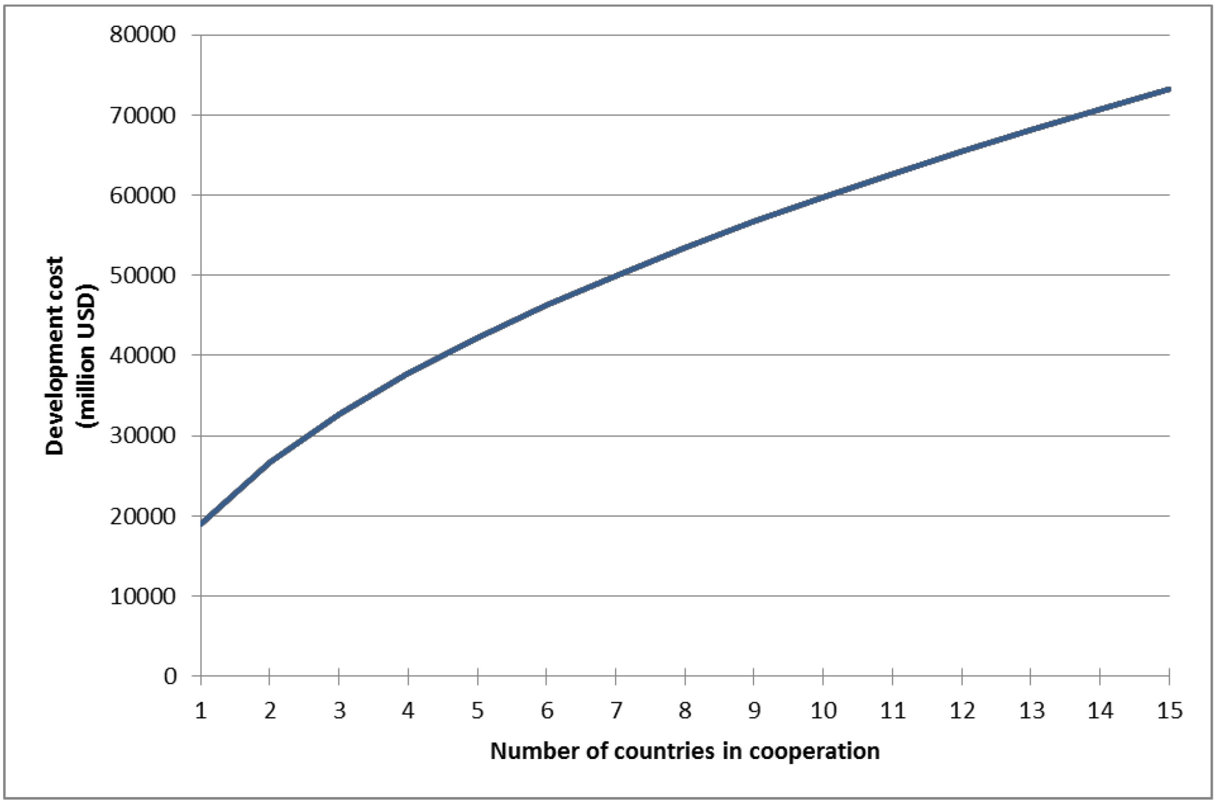


Figure 5-7: Development Costs as a Function of the Number of Countries in the Cooperation, with Transaction Costs.

If the *square-root-of-n* relationship holds true for Type-I cooperation, the development costs double when going from a single developer to a cooperation involving 4 countries. At 9 partners, the costs are tripled.

The benefits of adding collaboration partners must be weighed against the transaction costs associated with the collaboration. In the NF case study, the addition of a fourth and fifth partner can lead to increases to the average unit cost[4] (see Figure 5-8). Note that in all cases the resulting total unit cost is still much lower than the cost resulting from countries developing their own aircraft independently.

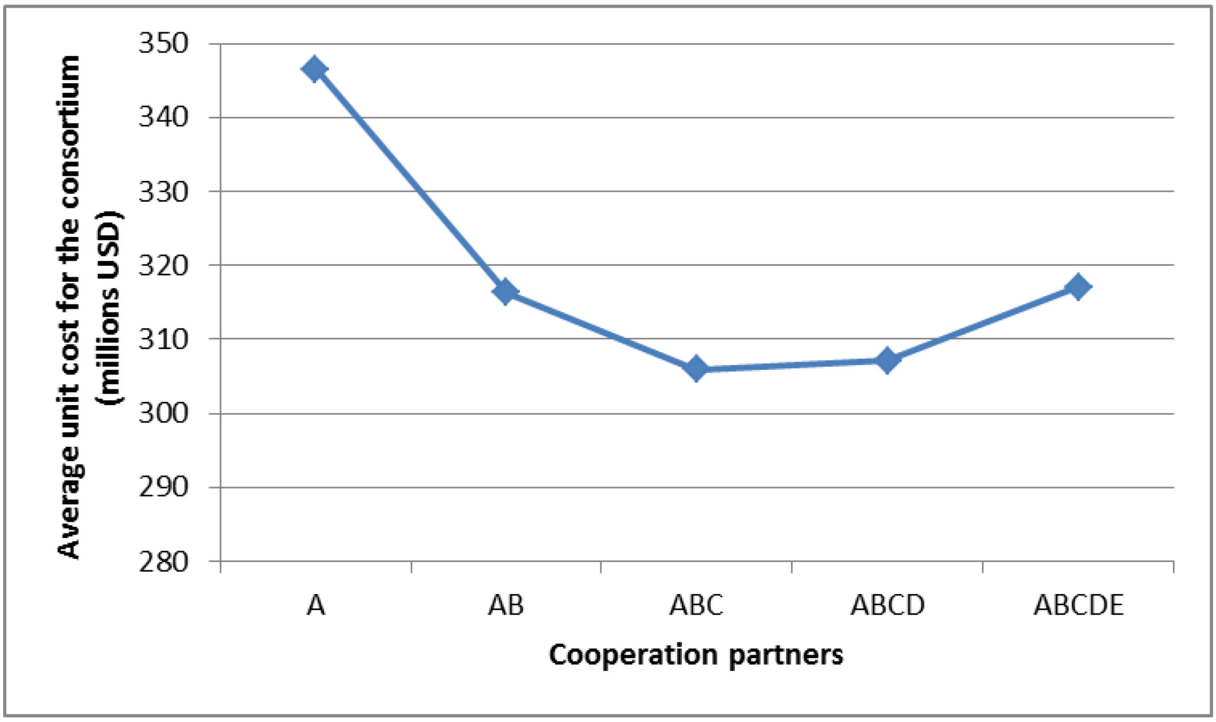


Figure 5-8: Average Total Unit Cost for All Countries in Different Cooperation Scenarios (in Millions of USD), with Transaction Costs and No Learning Effects.

The unit cost increase observed when Countries D and E join the cooperation is a result of the small fleets acquired by these countries. If countries acquiring smaller fleets contribute to the development costs proportionately to their share of the total production, they may not be able to contribute enough to the total development costs to offset the added transaction costs that result from their participation. In order for these cooperations to be beneficial, the countries acquiring smaller fleets must either increase their share of the development costs or offer other compromises such as relinquishing some national requirements.

The transaction costs can also cancel out some or all of the benefits achieved through learning effects. In this example, an 85 percent learning slope led to savings in the order of 52 percent on the final fleet acquisition cost for all countries in a consortium (when compared to the cost of developing the aircraft individually by each Nation). The addition of transaction costs to this calculation reduces the savings from learning effects to approximately 23 percent. In the case of a 95 percent learning slope the transaction costs outweigh the savings achieved through learning effects and increase the final average fleet cost by approximately 5 percent.

[4] We arrange here the partners by volume, where the largest partner is A, second largest is B, etc.

5.1.6 Conclusion

Table 5-3 and Table 5-4 summarize the calculations of the average total unit cost (including development) and the total fleet cost in the example presented above after factoring in the learning effects and the transaction costs. The tables show the scenario where countries act independently in the development and acquisition of a similar aircraft and the scenario where the countries participate in a consortium. The learning effects are applied to both scenarios although they are smaller in the first of the two since the production runs are smaller. Transaction costs only apply to the second scenario since there is no cooperation in the first scenario.

Table 5-3: Unit Cost (Including Development) for Each Country Considering a Learning Slope of 95 Percent and Transaction Costs (in Millions of USD).

	Fleet Size	Unit Cost (Million USD)		Savings	
		Nations as Sole Developers	Consortium Development	Million USD	%
Country A	120	300	259	41	13
Country B	90	356	259	99	27
Country C	70	418	259	160	38
Country D	40	627	259	368	59
Country E	10	2,059	259	1,800	87
Average		433	259	175	40

Table 5-4: Fleet Cost (Including Development) for Each Country Considering a Learning Slope of 95 Percent and Transaction Costs (in Millions of USD).

	Fleet Size	Fleet Cost (Million USD)		Savings	
		Nations as Sole Developers	Consortium Development	Million USD	%
Country A	120	36,044	31,065	4,979	13
Country B	90	32,026	23,299	8,727	27
Country C	70	29,294	18,121	11,172	38
Country D	40	25,077	10,355	14,722	59
Country E	10	20,592	2,589	18,004	87
Total		143,033	85,428	57,605	40

The potential savings when purchasing all 330 aircraft for the Alliance in this example are to the order of 58 billion dollars (or 40 percent) between the sole developer scenario and the consortium scenario, when considering a 95 percent learning slope and transaction costs.

Overall, in the study of the cost of developing and acquiring modern high capacity fighter aircraft such as the NF, the largest savings can be found in the sharing of the development costs between countries. The savings

are particularly large for countries acquiring a smaller number of aircraft. In this example the cost of acquiring 10 aircraft was reduced by close to 90 percent in a five-country cooperation. Measures taken to improve learning effects also hold the potential to increase the savings from cooperation. Even a small learning slope of 95 percent can reduce by close to one quarter the final cost of the aircraft.

On the other hand, transaction costs are also found to be significant and can outweigh savings from learning effects, even for alliances of no more than five participants. In this case, the cooperation between the 3 or 4 larger fleets is preferable to the 5-country cooperation. The addition of the fifth partner leads to increased average unit costs because the fifth fleet is too small to generate enough economies of scale to offset the added transaction costs. A model where the smaller Nations bear a larger burden of the development cost could offset the disadvantages to the larger Nations of adding more partners to the cooperation.

Finally, there are many other factors affecting development and acquisition costs that were not considered here, as discussed in detail in Chapters 3 and 4. The objective of the case study is to illustrate the scope of some of the important variables affecting the cost of the development and acquisition of military equipment.

5.2 CASE STUDY #2 – COMMON EDUCATION AND TRAINING

5.2.1 Context

5.2.1.1 Introduction

In order to become fighter pilots, officers must go through essential training and education. While the countries within the Alliance have different education and training models, in all countries future pilots begin their education with basic military and officer training. Since this is carried out in almost the same manner in each country, parts or all of the training and education could be completed through international cooperation.

In this case study, the costs of training fighter pilots is examined in different cooperation scenarios inspired by the organization of training in the SAS-090 participating Nations. By comparing scenarios, the areas and scale of cost duplication are highlighted.

5.2.1.2 Model of Training

After reviewing in some detail the education and training processes in Norway and Canada and in more general terms the education processes in other NATO Nations, a model of the education pipeline was created to guide the analysis of this case study. The different steps of the pilot education pipeline are summarized in Figure 5-9.

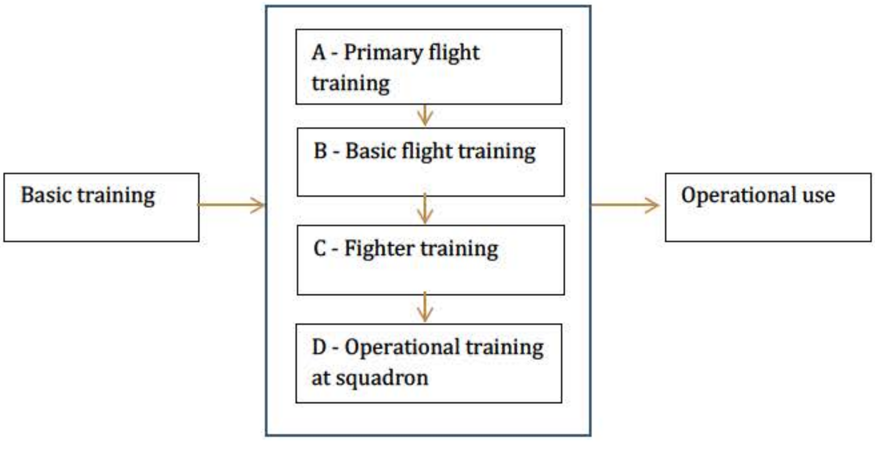


Figure 5-9: Generic Fighter Pilot Training Pipeline.

As a general rule, future pilots must complete basic training as well as primary flight training on a trainer aircraft such as the SAAB Safari in Norway or the Grob G 120A in Canada. Following the primary training (A), future pilots and jet pilots complete basic flight training (B) on a small trainer jet such as the Beechcraft T-6 or the CT-156 Harvard II in Canada. Since this is specialized training, some countries, like Norway, send their pilots to other countries for this phase of training. From the basic flight training and until they are ready to join an operational squadron, the Norwegian pilots are trained in the United States. In Canada, this phase of training (B) is open to other NATO Nations through the NATO Flying Training in Canada (NFTC) arrangement. Following the basic flight training, future fighter pilots continue to a more advanced phase of training (C), where they fly a trainer fighter aircraft. Finally the pilots return to an operational (or operational training) squadron to complete their formation (D).

5.2.1.3 Scenarios of Cooperation

From an economic perspective, the education of pilots is a production process just like the production of aircraft examined in the first case study. The measure of output in this production process is the yearly throughput of officer cadets who have completed pilot training.

The costs associated with the production of fighter pilots consist of a fixed component and a variable component. The fixed costs include the infrastructure and equipment necessary to conduct the training while the variable costs are proportional to the number of students receiving the training and to their usage of the equipment and supplies. The ratio of fixed and variable costs depends on the country, the fleet size and the phase of training.

The NF cost breakdown, derived with the Canadian Strategic Cost Model (SCM) and described in Section 5.1.1, was used again here to establish cost estimates for the fighter pilot training process for different country specifications. The SCM was used to provide guidelines on the ratio of fixed and variable costs for the different categories of cost. The following assumptions are made in the calculation of training costs:

- The cost of pilots' salaries and first line maintainers is considered to be directly proportional to the Yearly Flying Rate (YFR).
- A salary adjustment factor[5] is applied where necessary to reflect the varying cost of labor in different countries.
- Operations and maintenance costs are also considered to be proportional to the YFR.
- Capital costs are proportional to the fleet size and unit cost only.
- 75 percent of the costs of running the operational training squadron are fixed and another 25 percent are variable and proportional to the pilot throughput (based on Canadian data).

With these assumptions it is possible to estimate the cost of training pilots for the hypothetical NF fighter aircraft for different countries, with different YFRs, fleet sizes and pilot throughputs.

Note that the NF cost breakdown also attributes to the fighter capability a portion of the costs of primary flight training and basic flight training which future fighter pilots complete before beginning fighter training. These phases of training have an even higher proportion of fixed costs (85 percent for air training and 83.5 percent for common training). However, they are not considered in the following scenarios since the focus of this case study is cooperation for fighter-specific training. Due to the high fixed to variable cost ratio, they nevertheless remain areas with high potential for cost savings through cooperation.

Figure 5-10 illustrates the yearly cost of training per graduating student (unit cost) for a country similar to Canada in terms of fleet size, yearly flying rate and student throughput. As can be seen in the figure, the cost

[5] Based the International Labour Organization (ILO) Key Indicators of the Labour Market (KILMNET) http://kilm.ilo.org/kilmnet.

of training one student decreases rapidly as the number of students trained increases. This is a result of the high ratio of fixed to variable costs in fighter pilot training.

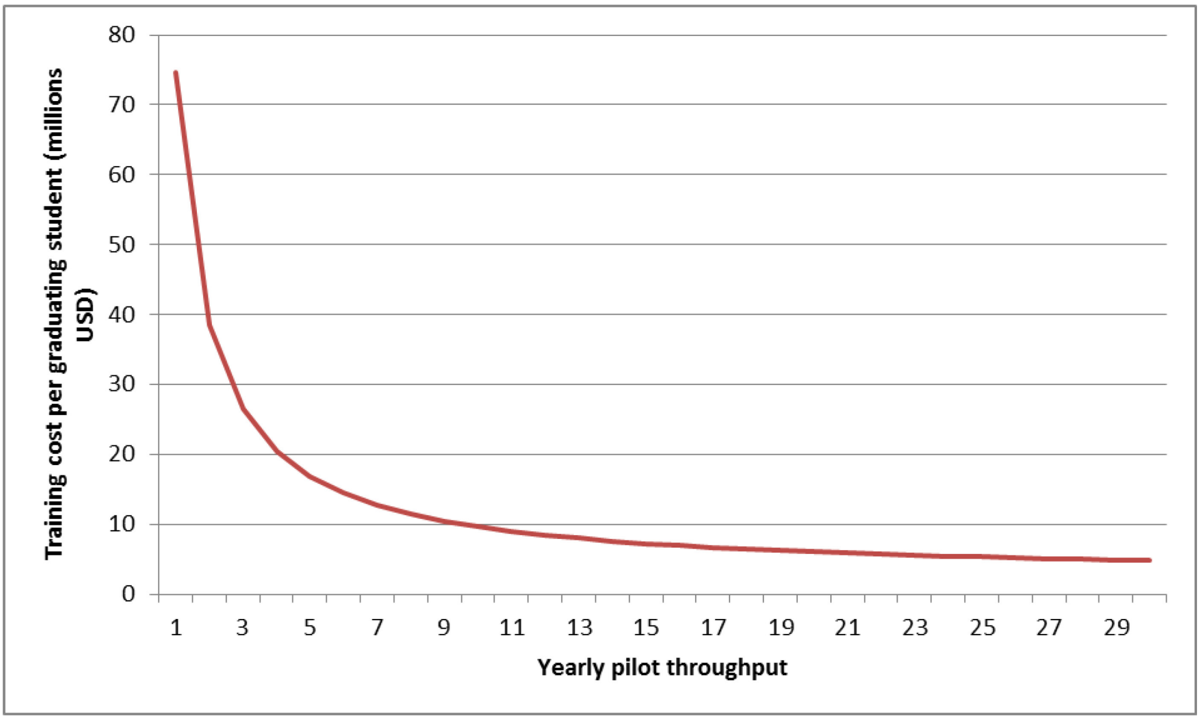


Figure 5-10: Variation of Unit Cost (Yearly Costs of Training One Graduating Pilot) as a Function of Throughput.

The yearly cost per graduating student in Figure 5-10 may appear higher than expected (or higher than often quoted in the media for example). This is due to the fact that the cost includes the amortization of all yearly fixed training costs (such as schools, base maintenance, medical or administrative support, etc.). The figures should be interpreted with caution since they are highly dependent on the accounting mechanisms used in the model. The description of the SCM in Annex B provides more detail on the cost accounting used here. The costs also depend on the many assumptions made, including the definition of a fully trained pilot which may vary between countries. The objective of this section is to highlight the drivers of cost and the areas where costs could be shared most beneficially rather than to provide accurate estimates of the current situation in any country.

The fixed costs in Figure 5-10 are also assumed to be the same for the training of 1 to 30 students. This is not an unreasonable assumption when the number of students stays below a certain critical mass. However, when the number of students is increased significantly, the fixed costs need to be adjusted to account for the expansion of the infrastructure and additional requirements for equipment. A larger pilot throughput requires additional investments in the fixed costs. When needed in the analysis presented hereafter, assumptions will be made regarding the scaling of fixed costs.

The following scenarios examine different forms of cooperation for the training of the NF fighter pilots in an attempt to estimate the extent of cost duplication and the potential for savings in each case.

5.2.2 Scenario 1: Individual Training and Education

As a baseline, this section considers a scenario where all countries operating the NF fighter aircraft conduct the complete training of their pilots on their own.

As in the previous case study, a group of five Nations with fleets of 120, 90, 70, 40 and 10 aircraft will be examined. The pilot throughput is assumed to be proportional to the fleet size and so the countries are assumed to produce each year 24, 18, 14, 8 and 2 pilots, respectively[6]. It is also assumed that the number of flying hours is proportional to the number of planes; the assumption is made that 100 planes fly 15,000 hours in one year[7]. For simplicity the cost of labor is considered equivalent in all countries.

The parameters of the example are summarized in Table 5-5.

Table 5-5: Example Alliance for the Study of Cooperation in Training and Education.

	Fleet Size	Pilot Throughput	Flying Hours
Country A	120	24	18,000
Country B	90	18	13,500
Country C	70	14	10,500
Country D	40	8	6,000
Country E	10	2	1,500
Total	330	66	49,500

The cost of training fighter pilots in each country is estimated through the scaling of the NF cost breakdown structure presented earlier. The cost estimates include the cost of fighter specific training as well as a portion of all general services (health care, housing, food, etc.) attributed based on the number of pilots being trained.

Table 5-6 shows the cost of training fighter pilots for each country. The estimates represent a yearly average, based on a 30-year cost profile.

Table 5-6: Yearly Average Training Cost for 5 Countries in a Baseline Scenario (in Millions of USD).

	Total Training Cost (Million USD)	Unit Cost (i.e. per Graduate) (Million USD)
Country A	130.2	5.4
Country B	115.8	6.4
Country C	106.1	7.6
Country D	91.6	11.5
Country E	77.1	38.6
Total	520.8	–

6 The approximation used is 0.2 graduating per plane on the fleet based on Canadian data.

7 Based on SAS-090 participating countries' data.

The total training cost for the Alliance in this example is approximately 521 million USD (Table 5-6), of which 391 million (75 percent) is expended on fixed costs. The average unit cost paid by countries in the Alliance is 7.9 million. The unit cost paid by each country depends on the student throughput. The large difference between the cost of training one student in Country A and in Country E is a consequence of significant fixed costs being distributed on a relatively smaller number of students in Country E[8].

The following sections examine scenarios where countries in the Alliance join their training in order to reduce the total fixed costs paid by the Alliance and achieve a lower average unit cost.

5.2.3 Scenario 2: Cooperation Between Three Nations

As a first example of cooperation, the situation where Countries B, C and E are pooling their training of fighter pilots is considered. Country B, in this case the country with the lowest unit cost, is providing the training facilities and provides training for future fighter pilots from Countries C and E.

The cost of training estimated here is based on the assumption that Country B has spare training capacity and can increase the number of students trained from 18 to 34 per year without increasing fixed costs. The estimates also are based on the assumption that Countries C and E would be able to completely eliminate the fixed costs related to fighter training in their country. This is a somewhat unrealistic expectation as the infrastructure and equipment required for the fighter training may be shared with other training programs. In addition, the costs associated with the phasing-out of the programs are not considered here. The cost estimates provide a picture of a steady-state solution where training has been organized differently. Additional costs related to the management of the cooperation programs would be incurred by all countries in the cooperation[9]. Although those costs are not estimated here, the difference between the baseline scenario and the cooperation scenario gives an idea of the funds that would be available for the management of the cooperation programs for the countries participating in the cooperation. The aim of the exercise is to illustrate the extent of duplication and the scale of potential savings.

The cost estimates for fighter pilot training programs in the baseline and in the 3-country cooperation scenario are shown in Table 5-7.

Table 5-7: Yearly Average Unit Training Cost in Scenarios 1 and 2 (in Millions of USD).

	Pilot Throughput	Unit Cost (Million USD)		Difference (%)
		Baseline – Scenario 1	Cooperation – Scenario 2	
Country B	18	6.4	4.5	29
Country C	14	7.6	4.5	40
Country E	2	38.6	4.5	88
Average		8.8	4.5	37

The cooperation scenario in this case results in unit costs that are approximately 29 percent, 40 percent and 88 percent lower than the baseline scenario for Countries B, C and E respectively. In other words, there are savings to be made for Country B if the cost of managing the cooperating program is less than 29 percent of the total cost of running the fighter training program independently (similarly for Countries C and E).

8 The fixed costs per country are based on data from the technical team's participating Nations.

9 These would fall under the definition of transaction costs, defined in Section 4.1.2.

In general, for the Alliance, the cost of training one student is 37 percent larger in the baseline scenario than in the cooperation scenario.

As mentioned earlier, the assumption in this scenario is that Country B has the capacity to train the additional students with the existing infrastructure and equipment. The next scenario considers the case of a larger cooperation where additional costs are expected to be incurred for the expansion of the training facilities.

5.2.4 Scenario 3: 5-Country Cooperation

In Scenario 3, a larger cooperation is examined. In this case, the 5 countries of the hypothetical Alliance share the training of their fighter pilots, using the facilities of Country A where the unit cost is the lowest.

Since the number of students trained in Country A now goes from 24 to 66, it is reasonable to expect that some investments will be required to upgrade the existing facilities and equipment. It is not straightforward to estimate the cost requirement for the expansion of the infrastructure because it depends on many factors (economic and non-economic) that are not treated in detail here. However, it is possible to look at the range between the best and worst case scenarios. In the best case scenario, the facilities of Country A have enough capacity to accommodate all students and no additional investments are required. In the worst case scenario, the infrastructure costs would be increased by 150 percent since the pilot throughput is increased by 150 percent. The increase in fixed costs can be represented by a factor μ which equals 1.0 in the best case scenario and 2.5 in the worst case.

The formula for calculating the unit cost in Country X (noted *UC(X)*) can be expressed as:

$$UC(X) = \frac{(FC(A) \times \mu + VCU(A) \times S(A))}{S(A)} \times S(X)$$

where *FC(A)* is the average yearly fixed cost for Country A and *VCU(A)* the variable cost per unit per year for Country A. *S(A)* is the average number of students graduating each year in Country A (and *S(X)* the average number of students graduating each year in Country X).

Table 5-8 shows the yearly cost of training one graduate (unit cost) in Country A, with different multiplication factors (μ) applied to the fixed costs.

Table 5-8: Unit Cost in Scenario 3 for Different Fixed Cost Multiplication Factors (μ).

μ	Unit Cost (Million USD)
1.0	3.5
1.5	4.1
2.0	4.6
2.5	5.2

It is clear from Table 5-8 that the average unit cost for the countries in the Alliance is less in cooperation scenario 3 than in the baseline scenario, even when the fixed costs are increased by 150 percent (5.2 million USD vs. 8.8 million USD).

The increase in fixed costs was analyzed in a Norwegian study based on the KOSTMOD[10] cost model. According to this analysis, different categories of training-related fixed costs increase by factors ranging from 7 percent (infrastructure) to 27 percent (staff) every time the number of students doubles. Based on these figures it appears that a factor $\mu = 1.5$ is actually a conservative upper bound on the increase in fixed costs for the cooperation scenario examined here (i.e. in other words the actual increase will most likely be less than 1.5).

Table 5-9 shows the estimated unit cost in Scenario 3 in comparison with the baseline scenario (Scenario 1) when $\mu = 1.5$.

Table 5-9: Yearly Average Unit Training Cost in Scenarios 1 and 3 (in Millions of USD).

	Pilot Throughput	Unit Cost (Million USD)		Difference (%)
		Baseline – Scenario 1	Cooperation – Scenario 3 $\mu = 1.5$	
Country A	24	5.4	4.1	25.3
Country B	18	6.4	4.1	37.0
Country C	14	7.6	4.1	46.6
Country D	8	11.5	4.1	64.6
Country E	2	38.6	4.1	89.5
Average		8.8	4.1	53.9

As shown in Table 5-9, the 5-country cooperation is significantly less costly than the individual training scenario (baseline) with all countries seeing potential cost reductions, even after accounting for the cost of increasing the capacity of the training infrastructure and equipment. The 5-country cooperation is also more beneficial than the 3-country cooperation in terms of unit cost.

The same caveats mentioned in the previous scenario also apply here. In particular, the costs of managing the cooperation program are not considered. However, the difference between the unit cost in the baseline scenario and in the 5-country cooperation scenario gives an idea of the scale of the funds available for program management. Based on the scale of the potential savings identified here, it is reasonable to expect that the added program management costs would not cancel out the benefits of cooperation.

5.2.5 Conclusion

The two scenarios of cooperation indicate the potential for significant savings through cooperation on the training of fighter pilots, even when the cooperation involves investments to increase the capacity of infrastructure and equipment. Figure 5-11 illustrates the unit cost achieved in the baseline scenario (individual training, blue in the chart) and the two cooperation scenarios (orange in the chart).

[10] KOSTMOD is a database program developed at FFI over the last 25 years. It is used at FFI for analysis of operations and procurement costs for different force structures and is well suited for cost-effectiveness analysis and risk analysis. A description is available at: http://ftp rta nato.int/public//PubFullText/RTO/TR/RTO-TR-SAS-027///TR-SAS-027-ANN-H-P9.pdf (accessed January 25, 2013).

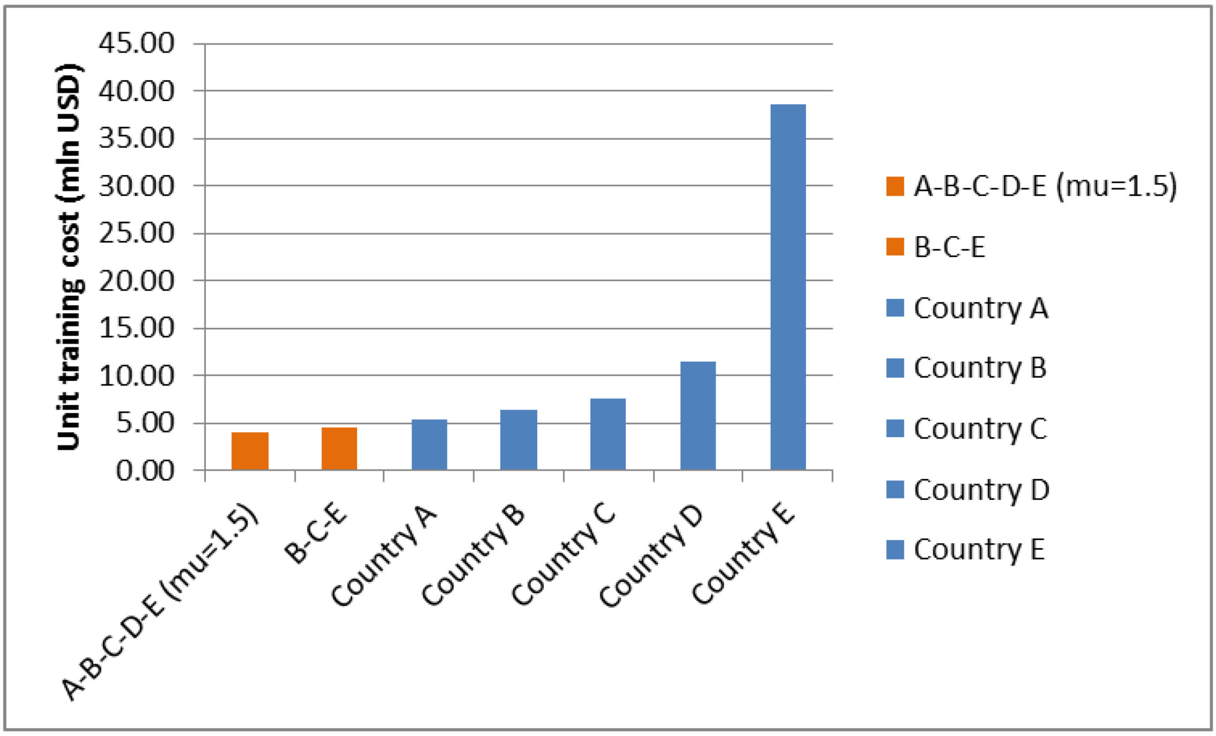


Figure 5-11: Unit Cost of Training in the Three Scenarios of Cooperation.

For countries with small pilot throughputs, both cooperation initiatives are beneficial, but the larger scale cooperation only provides marginal additional benefits. For countries with the larger pilot throughputs, the larger-scale cooperation brings substantial added benefits.

As many countries start to gradually reduce the size of their fleets, and accordingly the number of pilots trained, the benefits from cooperation in pilot training will increase for all participants.

It is important to remember that the results shown in this case study are not derived from an actual, real-life cooperation effort but are based on historical costing data. The results also stem from a steady-state situation where cooperation arrangements are already in place and no phasing-out or residual costs are incurred by the countries that are outsourcing their training. As mentioned, the program management costs (transaction costs) are also not accounted for – neither is additional travelling costs that might arise due to the cooperation arrangements. Despite these limitations, the scale of potential savings is an indication of the extent of cost duplication and overcapacity in a scenario of individual training which is close to the current situation for many NATO Nations.

Finally, in order to maximize benefits, the country performing the training should be the country which can train students with the smallest unit cost. While in general the country with the largest original infrastructure and student throughput has the lowest unit cost, a smaller unit cost can also result from factors that were not examined here such as the comparative cost of labor. The trade-off between the lower cost of labor and the cost of increased availability and capacity of staff and infrastructure would need to be examined to confirm the most cost-effective cooperation arrangement.

5.3 CASE STUDY #3 – COMMON OPERATIONS

5.3.1 Context

5.3.1.1 Introduction

Over the past decades, modern fighter aircraft have played a key role in air power, and are therefore viewed as one of the most important assets of NATO air forces. As a consequence, international cooperation within the NATO Alliance has been designed to allow countries to maintain a high degree of national independence. In the operational domain, cooperation between NATO Nations has been mainly limited to peacetime exercises, support activities during deployed operations and a limited handover of aircraft to NATO command, such as Quick Reaction Alert (QRA).

This case study examines whether operational benefits can be gained through cooperation without compromising national independence.

5.3.1.2 Requirements and Challenges

In order to achieve operational benefits with the pooling of aircraft and pilots, a high degree of standardization, commonality and interoperability is required. Despite this, cooperation initiatives can be beneficial with a relatively low level of integration, allowing participating countries to retain national command over the assets.

With a high degree of commonality, both in aircraft configuration and training syllabus for pilots and maintainers, the participating Nations could conceivably exchange aircraft, pilots and maintainers. Each Nation's air fleet could thus be viewed as belonging to one large fleet, and hence as increasing the total fleet's fighting power.

While the level of integration required for aircraft and pilot pooling is relatively low, the cooperation itself could serve as a building block for higher levels of integration. For instance, integration between Nations could be increased by following the same procedures and certification regimes. As a result, the aircraft could be bought off-the-shelves and logistics carried out nationally with broader cooperation coming into play only in the case of war, national crisis or deployment operations – and then only to increase the fighting power.

There are several challenges tied to this example, not the least of which is the ability to maintain the conformity of aircraft configurations between Nations over time. Other challenges include the use of highly classified systems that are often kept under national control, such as electronic warfare capabilities or language and cultural barriers.

5.3.1.3 Three Missions

National defence planners with a finite budget face a multi-dimensional dilemma consisting of designing fleets to perform three main missions:

- High intensity operations;
- Prolonged low intensity operations; and
- Quick Reaction Alert (QRA) (24/7).

Each mission leads to a different set of constraints on the design of the fleet and support structure. For instance, the main constraint for high intensity operations relates to the availability of aircraft which is determined by the short-term maintenance capacity. On the other hand, the ability to conduct prolonged low intensity operations is determined by the long-term maintenance capacity. Finally, the number of combat ready pilots is critical in determining a Nation's capacity to perform QRA watch.

Today, many Nations in the NATO Alliance share the same type of fighter aircraft, and each Nation optimizes its resources according to their own criteria. A fleet will inevitably be optimized for the mission that is deemed to have the highest strategic priority, leaving the fleet with a suboptimal configuration for the other missions. If those Nations had the same aircraft configuration, the same pilot skills up to a certain level and mechanics certified to work on each other's aircraft, the Nations could fill each other's gap when needed.

The potential of cooperation is examined in more detail below for each of the three missions. The focus of this case study is to quantify the operational benefits of cooperation rather than the economic benefits, as was done in the previous two case studies.

The operational benefits are estimated with the use of the Norwegian FLYT2 model (described in Annex A). The FLYT2 model is used to calculate a mission capable rate under different constraints related to the number of aircraft, maintenance personnel and flight schedules.

5.3.2 Mission 1: High Intensity Operations

In a NATO Article V operation, either at home or abroad, the high intensity operations could require a high number of sorties in a short period of time. Any peacetime training and worker regulations requirements are expected to be lifted both for pilots and maintenance personnel. In such a situation, fleets are typically flown extensively and fuselages queue up for short-term maintenance.

As an example, a group of four Allied Nations deploying to conduct a high intensity operation for 30 days is considered. All four Nations have 50 active fighters, of which they deploy 12. The pilot to aircraft ratio used is in accordance with ACO forces standards for deployment [72]. This example includes a relatively large number of flying hours, both in terms of the number of sorties and the sortie duration. In addition, each Nation must uphold their QRA commitment to NATO and training at the home base.

Two scenarios are examined using the FLYT2 model. In the first scenario (Scenario 1), it is assumed that all Nations deploy individually while in the second scenario (Scenario 2) pilots, maintainers and aircraft are interchangeable in such way that the fleet could be operated as one. The simulation tool FLYT2 is used to find the minimal maintenance capacity required to achieve more than 90 percent availability, once it has been established that short-term maintenance capacity is the bottleneck. The two scenarios are illustrated in Figure 5-12.

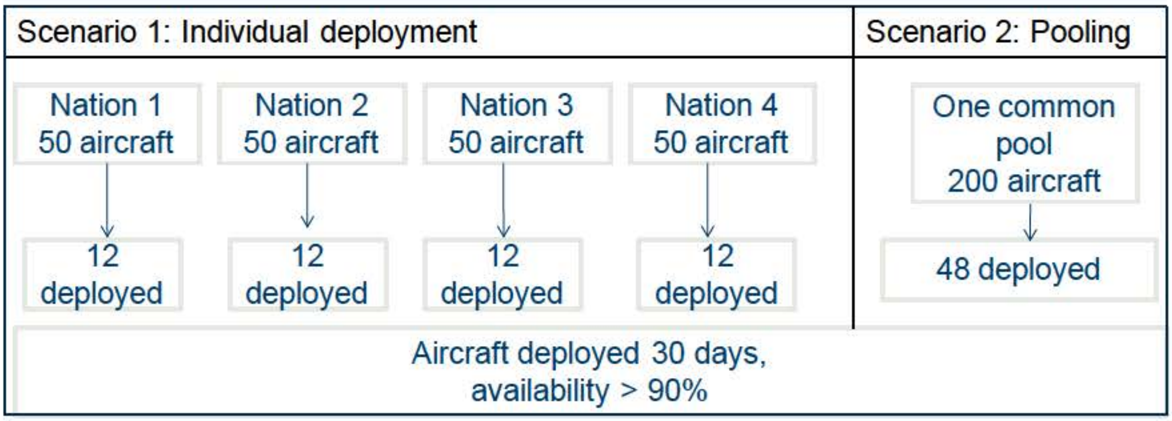


Figure 5-12: Two Configurations for 4 Allied Fleets Conducting a High-Intensity Operation.

Not surprisingly, it is found that the mission capable rate is lower for the four individual Nations (Scenario 1) compared with the common fleet (Scenario 2). Further, the bottleneck seems to be queues building up on

short-term maintenance lines. By merging maintenance capacity, maintenance scheduling is optimized and workers have a higher utilization factor. In order to achieve the same mission availability factor (> 90 percent) in both scenarios, the four Nations deploying individually need some 5 – 10 percent increased short-term maintenance capacity, mainly workers, compared to a common fleet.

The improvements in capacity come from the fact that by treating the aircraft belonging to the four Nations as one fleet (Scenario 2), the model does not discriminate between higher availability due to better allocation of maintainers and interchanging of aircraft. Some increased availability stems from the transfer of aircraft between Nations that helps even out variance in the snag rate (the rate at which equipment suffers unexpected failures or difficulties). In the case where national caveats could apply, interchanging aircraft might be difficult without changing the flag the aircraft is carrying as well. Therefore the solution in some cases requires a system to be in place that ensures the equipment is carrying the right flag.

Nations organize the operation of their fleet of fighter aircraft differently depending on worker regulations, military ambitions, technological level, maintenance philosophy, etc. The Norwegian specific parameters are thus not valid for other Nations[11]. However, the general trend, i.e. fewer required aircraft, is expected to be valid. Also, in cases where Nations do organize differently, cooperation in operations would enable the utilization of each Nation's advantages.

5.3.3 Mission 2: Prolonged Low Intensity Operations

In low intensity operations, the sortie rate could for prolonged periods be higher than normal. In this case the maintenance depot capacity could be insufficient to meet the required aircraft availability.

In this example, the four Nations deploy on a rotational basis, for 90 days each, 12 aircraft and pilots according to ACO forces standards for deployment [72]. The same input parameters are used as in the previous mission, except for the sortie generation rate and the deployment time. The former is reduced while deployed time has increased to 90 days per Nation per rotation, and there is an additional requirement that forces are regenerated to sustain the rotation cycles endlessly.

In a scenario where Nations operate individually (Scenario 1), FLYT2 simulations indicate that 34 aircraft[12] and 30 pilots per Nation, for a total of 136 aircraft and 120 pilots, are necessary to have an on-going operation with 12 deployed aircraft.

If the deploying Nations cooperate such that maintainers, pilots and aircraft are interchangeable (Scenario 2), the combined force could be operated as one common fleet. Figure 5-13 illustrates the principle. In this example, Nation 2 is involved in an operation, deploying pilots and aircraft while the other Nations are supporting the operation by providing maintainers for short-term maintenance, by training pilots to combat ready status and by undertaking aircraft overhaul.

[11] The aircraft availability calculated with the FLYT2 model is based on classified input parameters from the Norwegian Air Force. Sensitivity analyses reveal that these numbers are highly sensitive to national input parameters, such as spares availability, workers' regulations and requirements for pilot combat ready status. By adjusting these input parameters, the results change considerably. This implies that the savings achieved by requiring fewer maintainers could both be higher and lower, depending on which Nations are involved in the cooperation. It is also emphasized that the model is constructed for a Norwegian fleet size, hence for considerably larger fleet sizes there could be bottlenecks not identified, reducing the overall performance.

[12] In the simulation we have identified the required numbers of aircraft to maintain the deployment of 12 aircraft. Iterations of the model could be run to find the number of aircraft possible to deploy with a national base of 50 aircraft per Nation to be consistent with the number of aircraft used in Mission 1. However, the cases are only used to illustrate the principles and magnitude of saving, hence time consuming iterations have not been run.

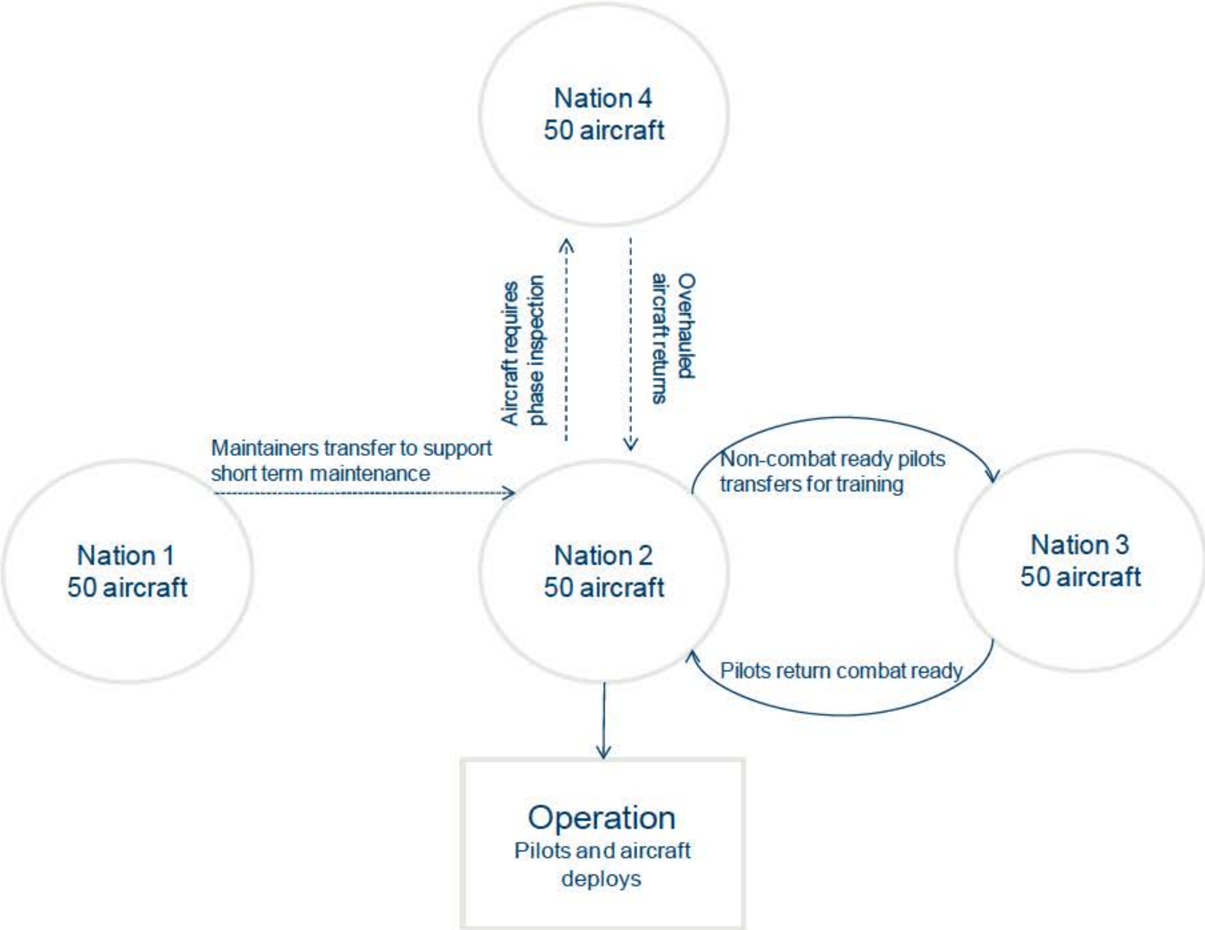


Figure 5-13: Illustration of the Pooling and Sharing Principle for Mission 2.

Note that in this scenario, deployments could still be undertaken individually. The operational gain in this scenario is a result of the utilization of the partner Nations' capacity to maintain aircraft and train pilots. See Figure 5-14 for an illustration of the simulation in the two scenarios.

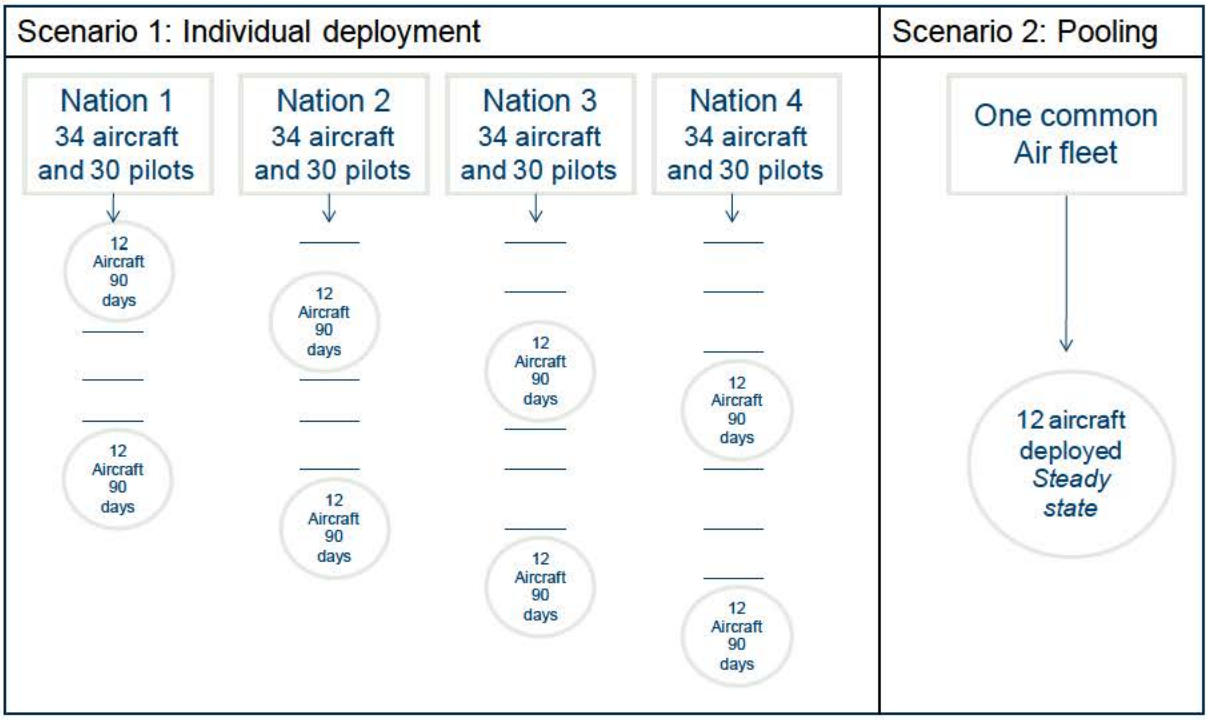


Figure 5-14: Results of FLYT2 Simulation Calculating the Number of Aircraft and Pilots Required for Mission 2.

Simulations show that in Scenario 2, the same operational requirements can be met with 122 aircraft instead of 136, which yields a saving or efficiency improvement of 14 aircraft. The number of required pilots is unchanged. In addition to the potential to improve efficiency corresponding to 14 aircraft by cooperating, a detailed analysis of the simulation data reveals another, possibly larger operational advantage. In the scenario where each Nation deploys individually, maintainers need to deploy along with the pilots and aircraft, reducing the capacity to maintain and produce flight hours at the home base. As a consequence, the numbers of mission qualified pilots and aircraft drop after the deployment and need to be rebuilt. The bottleneck in the simulations is the resources required to build up combat readiness for the next deployment. This implies an increased vulnerability in the reconditioning phase. In the scenario where the four national fighter fleets are regarded as one, the model shows a steady-state behavior without major fluctuations and reconditioning phases. Hence, the four Nations as a whole are better prepared for unforeseen events during the deployment phase.

Having aircraft with a common configuration can also lead to logistical benefits, as deployments can be undertaken without the need to move support equipment, spares and tooling. The logistic footprint would be reduced by having this equipment left behind for the next cooperation partner.

5.3.4 Mission 3: Quick Reaction Alert (24/7)

The NATO QRAs consist of a pair of aircraft on high readiness under NATO command. However, the practice is that Nations responsible for QRA use their own pilots and aircraft, and are eligible to transfer those back under national command. Actual loss of command and control is thus not necessarily perceived to be real.

In a crisis scenario there could be a situation demanding several different QRA-sites, the number of flight hours does not necessarily increase above the normal peace time level. This is because the increased readiness level requires aircraft to be on stand-by, and only training to maintain combat ready pilots is

required. During such a situation fuselages are generally not a concern, but the number of combat ready pilots that can enter the shift rotations is. If the situation is prolonged, pilots must attain their peacetime training and rotations in order to keep their combat readiness status.

In order to keep one QRA-site on high readiness for 24/7 for a prolonged period, the number of pilots needs to be in the range 15 – 20 even though only two are on duty at any given time. The main reason why the on-guard to off-guard ratio is closer to 10:1 rather than 5:1, which would be natural for other 24/7 arrangements, is that the pilots continuously must train to maintain their combat readiness status.

The NATO Air Policing in the Baltic States is an exception to the typical QRA arrangements, where Allied Nations take turns to deploy aircraft and personnel for one QRA stationed in the Baltic States. This case of specialization is the result of the Baltic States having to date no capacity on their own to establish a QRA. Their alternative to having Allies patrolling the skies is therefore the absence of this capability. Another motivation for this arrangement is that the level of integration could arguably be viewed as limited. Deploying Nations require a minimum of host Nation support, for instance Nations readily use their own forces for close protection security.

Taking over the NATO QRA could be achieved in a similar manner to Allied Nations today patrolling the skies of the Baltic. However, the logistic footprint is large, as the supporting Nation deploys a number of aircraft, pilots, maintainers and supporting personnel. If, instead, pilots are checked out on the host Nation aircraft fleet, on-line aircraft would be the full responsibility of the host Nation. The only required logistics in this case would be the shipment of two pilots, ready for their duty turn.

Even if the host Nation in such a scenario receives substantial support measured in the number of combat ready pilots, the resources required are minor in comparison. The supporting Nation would probably have to involve a number of pilots in the higher end of the 15 – 20 range to man the QRA watch, as travelling time is taken into account, but no extra training is required. During peacetime, it is assumed to be trivial for a supporting Nation to spare pilots for the QRA, while at the same time maintaining its own readiness training.

Finally, it is worth noting that in the event that an operation does not involve all cooperating Nations, there will be spare capacity that could support the participating Nations. Thereby, the fighting power of the Nations involved in an operation could be greatly increased while direct involvement is not undertaken by the other Nations. An example of this includes pilots from supporting Nations manning the QRA, as described above. Further examples involve maintenance support and training of partner pilots to combat ready status.

5.3.5 Conclusion

From the examples above we see that there are indeed also operational benefits to be had for the pilot and aircraft pooling case study. However, these operational benefits depend on the scenario and how each Nation has optimized their air force. Missions 1 to 3 above cover the different operational availability requirements that capability planners must weight against each other, namely:

- Aircraft availability for high intensity operations;
- Aircraft availability for low intensity operations; and
- Number of combat ready pilots available for operations.

For each type of mission the study finds that the operational benefit that four typical Nations can achieve by aircraft and pilot pooling corresponds to an increase of about 10 percent in their capacity.

For high intensity operations, availability simulations have shown the effect of pooling corresponds to be an increase in maintenance capacity in the range of 5 – 10 percent, adding to the savings from Cases 1 and 2.

In the low intensity example the direct efficiency improvement was found to be large. Not only was the need for aircraft reduced by some 10 percent, but the four cooperating Nations were able to maintain their combat readiness during the deployment period. In operational terms this is a significant advantage, as Nations deploying a substantial part of their fighter fleet lose their ability to simultaneously handle unforeseen events, in parallel with an increasing number of aircraft in the queue for depot maintenance. The third mission illustrates the benefits of pooling resources to increase the availability of combat ready pilots. By ensuring full commonality of their fighter fleet, cooperating Nations could readily man an Allied NATO QRA, thereby increasing their capability by the equivalent of 15 – 20 pilots and aircraft.

The relative advantages of pooling, as depicted in the above examples, will be larger as the fleet size becomes closer to critical mass and smaller for Nations with large uniform fleets. The cooperating Nations in the examples presented here have fighter fleets consisting of 50 aircraft. This is not an untypical order of magnitude for active fleets within NATO, as most member states with the exception of the US, range from zero to a couple of hundred fighters in total. Thus, in general, operational benefits in the range demonstrated here should be attainable for most small- and medium-sized fighter Nations by closer cooperation within NATO.

In addition to the savings that are quantifiable through operational effectiveness, this report also finds large benefits that are more difficult to quantify in economic terms. Equipment harmonization renders possible cooperation in the operational theatre, which leads to significant operational benefits that go beyond direct cost savings. Commonality also has the potential to drastically reduce the requirement for support and supply functions during operations, i.e. the logistic footprint. Finally, the report has also demonstrated that pooling can increase resilience.

In this case study, the focus has been on operational benefits, and not directly tied to cost savings. However, as shown by the first two cases, uniform configuration gives rise to potential savings in the support area. By implementing aircraft pooling, uniform training and configuration standards are necessary, which in turn gives potential for cooperation and savings across the whole spectrum of support activities.

5.4 MAIN CONCLUSIONS FROM THE CASE STUDIES

Through three different case studies, covering Type-I and Type-S cooperation and the military *support* and *capability* levels, the report has shown that there is considerable potential for savings through cooperation. In *Case Study #1 – Common development and acquisition,* the savings on the cost of a new aircraft were on average found to be about 40 percent, taking into account transaction costs. In *Case Study #2 – Common education and training*, the reduction in training costs was of more than 50 percent when compared to the scenario where all Nations undertook their own training. Finally, *Case Study #3 – Common operations,* showed considerable operational benefits from pooling assets, quantified to a range of 5 – 10 percent improvement in maintenance availability for relatively low levels of integration. The case studies have shown average savings for the cooperating countries ranging from 5 percent to 50 percent, revealing both large magnitude and variance.

While the economic savings in Case Study #1 stems from both learning effects and distribution of fixed costs on larger production numbers, it was only the latter effect that was taken into account for Case Study #2. The scale effect taken advantage of in Case Study #3 was the more efficient use of resources as the fleet size increases. This effect is particularly strong for systems whose numbers of platforms are close to critical mass.

Although the NATO fighter has some unique properties which make direct comparison with other platforms difficult, the mechanisms by which savings are attained in the case studies are general and applicable to a range of different platforms. The order of magnitude of the savings derived by the case studies thus gives an

indication of the potential savings in general. It should be noted however, that the transaction costs addressed in Chapter 4 and estimated in Case Study #1, could vary considerably between systems.

Chapter 6 – IMPLICATIONS FOR NATO NATIONS

The objectives of this study have been to investigate the cost efficiency implications of international cooperation for Alliance members and to propose a framework for determining which collaboration initiatives are most likely to lead to economic benefits. Based on the case studies it is obvious that there is a substantial potential for savings in the Alliance. In order to realize this potential, NATO members need to:

a) Cooperate more; and

b) Choose the right cooperation initiatives.

The chapter addresses these two points, starting with the need for more cooperation.

6.1 COOPERATION – AN IMPERATIVE FOR NATO

With rising unit costs, more Nations facing problems with critical mass and significant cuts in NATO defence spending, partly as a result of the financial crisis, there is no doubt that international cooperation is a strategic imperative for NATO in the coming years. The ever-increasing equipment costs will inevitably lead to cuts in the number of units, pushing ever more weapon systems below the critical mass needed to operate efficiently. The fixed costs related to maintaining balanced defence structures will also be spread out to fewer and fewer units, increasing average unit operating cost. If the NATO defence spending trends from the last 25 years are to continue, this development seems inevitable. Even a moderate increase in spending is unlikely to shore up large-scale structural cuts.

The development where many small and medium-sized NATO Member Nations end up having to remove key capabilities in their defence structures will only aggravate the trend of the last decades, whereby NATO is becoming a two-tiered Alliance. The gap between those who can participate and those who cannot due to lower training standards, substandard technology and capability gaps is only increasing.

It is not possible to estimate the savings in NATO from increasing the scale and scope of the multi-national cooperation. However, the case studies in this report indicate the potential for cost savings ranging from about 5 percent to 50 percent, depending on the size of the Nation and the type of cooperation. This scale of savings suggests that increased cooperation is likely to lead to significant economic benefits for NATO Nations, with the largest savings potential for the Nations who need it the most, smaller Nations.

NATO leaders agreed on the Smart Defence initiative at the 2012 Chicago Summit, calling for pooling and sharing while avoiding uncoordinated cuts. The initiative has the potential to facilitate many of the cooperation efforts being recommended in this report, and can thus play a vital role in keeping NATO relevant and vital in the coming years. Until now, Smart Defence has focused on the *quick-wins*, identifying a range of different cooperative projects, but there are also proposals for more *radical* programs [73]. In order to use Smart Defence as the tool Rasmussen intended it to be, and help NATO Nations cope with the widening capability gap within the Alliance, Nations need to cooperate on a deeper level and in broader areas of defence than they do today. With the steady decrease in military purchasing power that most NATO Nations are experiencing, cooperation becomes not just a measure to save on defence expenses but also a matter of being able to afford having key capabilities at all. International cooperation is not just then an alternative to continued national activity, but the only alternative left except for disbanding the activity and capability all together.

There are numerous stories of successful and less successful cooperation initiatives within NATO. As seen throughout the report, the will and ability of a group of Nations to cooperate are affected by a number of social, political and military considerations. Balancing political and operational requirements against costs in a multi-national setting is a demanding process, within which the benefits lie. Cooperation can be organized

in different ways and the key to its success is identifying the optimal cooperation form, given both the partners' attributes and the area of cooperation.

6.2 WHAT SHOULD NATO MEMBERS COOPERATE ON?

This section addresses the issue of which areas NATO members should cooperate on. In order to bring structure to discussions of cooperation areas and cooperation types, this report has proposed a taxonomy. This is presented in Chapter 2, and illustrated in Figure 2-3. This taxonomy divides all cooperation efforts into 6 different categories, using the two dimensions *military level* (support, capability and service) and *cooperation type* (Type-I or Type-S). By grouping cooperation efforts this way, it is easier to make generalizations on when efforts will succeed and not, and what types of challenges they will face.

When choosing what to cooperate on, this taxonomy becomes highly relevant. Nations are faced with three defining choices:

a) In what areas of the armed forces structure to seek cooperation;

b) At what military level to conduct this cooperation effort; and

c) What cooperation type to opt for?

This section addresses these three questions successively.

6.2.1 In What Areas Should Nations Seek Cooperation?

The biggest driver behind gains from international cooperation is economies of scale. Economies of scale are usually largest in areas where a large share of fixed costs is observed. Countries should therefore assess the cost structure of their armed forces and identify areas that have the highest share of fixed costs. Different countries might compile different lists, based on national price differences and differences in the scale of each country's activities in a particular area. The submarines capability for instance may well be considered to have a large share of fixed costs in Country A, but a medium share fixed costs in Country B. If Country A has 5 submarines in its force structure while Country B has 15, Country A has fewer units on which to distribute the overhead costs related to training, education and maintenance.

Areas with high shares of fixed costs can be found throughout the armed forces. Activities as diverse as education, training, maintenance, logistics and operations are all likely to be represented on a short list of areas with a large potential for economies of scale.

A related aspect that needs to be considered when choosing areas of cooperation is the scale of the different capabilities. Areas that are approaching critical mass are very good candidates for international cooperation simply because they run the risk of being cut out of the force structure due their high unit costs. Capabilities that consume a large share of a Nation's total military expenditure are also natural candidates for cooperation because the absolute size of the savings is likely to be large there.

6.2.2 At What Military Level Do We Want to Conduct the Cooperation Effort?

After deciding what activity to expose to an international cooperation effort, the right military level of the cooperation needs to be determined. This report recognizes three different levels:

- The support level;
- The capability level; and
- The service level.

These levels have different sets of challenges and benefits. The degree to which scale and scope economies can be leveraged will in most cases increase when moving up from the support level to the capability level. Likewise, the benefits will again increase going from the capability level to the service level. Unfortunately, the less tangible political and industrial cost will in many cases also increase by moving to a higher military level. This trade-off between monetary savings and political hardship is of course not for this report to make, and is left to the politicians. The case studies, however, identified that potentially large gains can be realized by broadening cooperations from the support level to the capability level.

Political costs are often related to the loss of jobs and sovereignty, and in most situations a range of actors are likely to speak up in order to raise awareness about the size and nature of these costs. This report may serve to counterbalance these arguments by bringing awareness of the benefits of international cooperation.

6.2.3 What Cooperation Type Should NATO Opt For?

The choice of cooperation type is a basic and defining step in all cooperation efforts. Should cooperation be established with others on an integrated basis (Type-I), where all partners share production? In such an arrangement, each Nation still retains part of the control and some jobs related to the production of the service or good. Or should a specialized arrangement (Type-S) be chosen where one partner supplies all the others? The economic gains are the largest in the latter type of cooperation, but the political costs might be too high for some partners to accept. These trade-offs depend partly on whether the cooperation is centered on a supportive platform or a fighting unit.

Furthermore, opting for a Type-S cooperation can have advantages related to transaction costs. By having one Nation specialize and de facto lead the cooperation effort, several of the mechanisms that lead to higher costs in international cooperation can be dampened.

6.2.4 Recommendations for Bringing about the Needed Change in NATO

In order for these far-reaching changes to be fully implemented, NATO needs to stimulate and encourage international cooperation far more vigorously than before. Below, the report suggests a number of NATO-wide measures that will either lead to new cooperation initiatives being identified by the Nations or help facilitate the already identified and suggested cooperation initiatives.

6.2.4.1 Empowering the Special Representatives

As a means to help Smart Defence materialize, the Secretary General has appointed two special representatives in NATO. Currently these representatives mainly use Smart Defence to facilitate and coordinate Member Nations’ cooperation initiatives, acting as a sort of clearing house. Given that international cooperation represents an imperative for NATO, and that there are a wide range of potential obstacles slowing down the pace of cooperation in NATO, these special representatives need to a much larger extent act as change agents within the Alliance. In order for these representatives to have the required impact on national behavior, they need to have wide mandates for and powers to impact NATO policy. To the extent possible, the special representatives should be empowered to exert the needed pressure and influence on the member Nations in these arenas for cooperation.

6.2.4.2 Coordinating Long-Term Planning

NATO Nations need to start coordinating their long-term planning and capability planning in order for some degree of equipment commonality to be attainable. This is largely conducted nationally today, and NATO is usually informed after the fact. This way countries in the same alliance end up planning for procurement, maintenance and training nationally and in parallel, without being aware of the full potential for multi-lateral cooperation. This coordination could be performed in such a manner that Nations fully retain national control

and sovereignty over their long-term planning. By requiring upcoming decisions of a certain caliber to be reported to a NATO body, for instance ACT, all NATO Nations would quickly establish a list of potential cooperation partners. The types of decisions requiring pre-reporting could be significant investments, decisions of disbanding a capability or decisions regarding a planned cooperation effort with another country.

6.2.4.3 Centralizing NATO Equipment Procurement

The issue of equipment commonality could also be addressed by strengthening and changing the mandate of the NATO Support Agency (NSPA). NSPA is an agency that provides both equipment procurement and logistics services to NATO members. By funding a larger part of NSPA services over NATO budgets, Nations would be able to use their services free of charge or for a negligible fee. NSPA would then be able to pool the equipment procurement efficiently for groups of countries and also structure cooperation schemes for the logistics following the procurement.

6.2.4.4 Establishing NATO Units

By setting up NATO units, NATO could demonstrate cooperation Type-I on both a support and on a capability level. The C-17 cooperation is an example of such a unit, where NATO Nations contribute to a commonly produced good. By encouraging the establishment of further such units, NATO Nations gain valuable experience in participating in international cooperation. Further success in this area will also serve as success stories and best practices for other NATO Member Nations.

6.3 CHOOSING THE RIGHT AREA – A DECISION-SUPPORT TOOL

In order to provide decision-makers that are facing a specific cooperation with a set of decision criteria, the SAS-090 technical team has developed a decision-support tool based on the findings in this report. The tool is shown in Figure 6-1. The tool aims to help decision-makers think through the attributes of a particular cooperation, whether it is a new initiative, the assessment of an existing effort or the evaluation of proposed changes to a cooperation proposal.

Cooperation initiative:	SAS-090									
Factors	Economic			Political & industrial			Operational			Comments
	Pro	Con	N/A	Pro	Con	N/A	Pro	Con	N/A	
Economical:										
1. Large scale production has an advantage over small scale production (Economies of scale)										
2. Utilization of common resources by gathering two or more activities (Economies of scope)										
3. Larger production runs lead to effciency and learning improvements, thus reducing the unit costs (learning curves)										
4. Risk of opportunistic behavior										
5. Affect on national industry										
6. Implications of national standards and requiremetns										
7. Transport costs										
8. Risk of monopoly power										
9. Administration, negotiation & contract costs										
Other considerations:										
10. Technological transfer and knowledge spillover (eg. Sharing sensitive technology & information)										
11. Local community consequences (e.g. civilian employment)										
12. Language barriers										
13. Culture barriers										
14. Compromising on operational requirements										
15. Altered operational availability										
16. Alliance building										
17. Generating dependences										
18. Transfer of military knowledge through training & operationa experiences										
19. Contribution to interoperability (e.g. standardizing & harmonizing)										
20. Loss of national military expertise										
21. Enhanced deployment capability (e.g. reducing logistic footprint)										

Figure 6-1: SAS-090 Decision-Support Tool.

One of the main obstacles to deciding whether to accept or reject a specific cooperation initiative is comparing the economic and quantifiable factors with the non-economic and often non-quantifiable factors. While the non-economic factors affecting cooperation programs are varied and not easily quantifiable, especially not using a common unit of comparison such as dollar figures, they still must be assessed in order to determine whether cooperation programs have the potential to yield benefits. Their assessment is also essential in order to determine whether it is best to make necessary compromises to address them or whether it is best to avoid certain cooperation initiatives because the political or industrial factors will render them unsustainable or unprofitable.

The decision-support tool provides a systematic way to examine all the main non-economic factors that may affect cooperation efforts in order to initiate a discussion of the impact they may have on a specific cooperation program. The factors in the decision support tool are a synthesis of all factors and considerations presented in Chapters 3 and 4. Once completed, the decision-support matrix, in the form of an Excel spreadsheet, highlights potential problem areas. This might help a decision-maker to form a clear picture of the extent of the non-economic factors, and whether they might be serious enough to outweigh the potential cost savings. Ultimately the objective of the decision-support tool is to help decision-makers:

- Avoid engaging in cooperation efforts that are “not worth it”; and
- Avoid staying out of cooperation efforts where the hurdles are actually manageable and the benefits are substantial.

The principle behind the decision-support tool is simple; users go through each factor and determine whether it will impact the cooperation outcomes positively, negatively or not at all. For each factor, the users then assesses whether the impact is major, minor or insignificant. Finally the users can take a look at the assessment matrix as a whole to compare the negatives against the positives. The decision-support tool is intended to facilitate the required discussion, not to provide a definitive answer. Ideally an assessment of the potential economic benefits would have already been conducted and would be compared with the impact of the non-economic factors.

The SAS-090 decision-support tool can be adapted to the needs of the users. However, it is strongly recommended that it is not turned into a points-based system for coming up with a group decision, for instance by giving 10 points to factors that are beneficial and -10 points to factors that have a negative impact. The points-based approach is not recommended because the different factors will have varying importance in the different cases considered and their true impact will be better assessed through group discussions than by looking at an average score.

Chapter 7 – SUMMARY AND CONCLUSIONS

Economic austerity and rising unit costs of defence equipment are forcing Nations within NATO to think differently when it comes to their defence spending. The objective of the SAS-090 study and this report has been to investigate the cost efficiency implications that international defence cooperation can yield for NATO members.

In order to investigate this complex problem, a need for clarification of the different concepts of cooperation was identified. The report provides a new set of definitions on the cooperation types and the military levels at which cooperation can occur. A distinction is made between two main types of cooperation: Type-I *Integration*, where the cooperating partners are jointly responsible for the production of the defence good, and Type-S *Specialization*, where only one or a limited number of partners are responsible for the production of the defence good and other partners' access to the good is agreed upon through contracts. Cooperation can of course be organized in several ways, combining the two types to various degrees. The important point is to distinguish between the two main ways of organizing a defence cooperation agreement. This categorization was necessary in order to analyze the advantages and the disadvantages of cooperation and to make general recommendations. The recommended type of cooperation also depends on the nature of the goods or services that are at the centre of the cooperation. The report therefore separates and defines three main military levels:

- The lowest *support level*;
- The higher *capability level*; and
- The highest *branch of military service level*.

Through the use of economic theory, prior studies on the subject and lessons learned from present and former cooperation programs, the economic, operational, political and industrial benefits of cooperation have been identified. The report also looks closely into the potential disadvantages of cooperation. It covers not only the economic costs of cooperating, such as transaction costs and trade barriers, but also the operational, political and industrial disadvantages. Main recommendations are drawn from assessing how the advantages and disadvantages are linked to the different goods and services, the level of the cooperation and the chosen type of cooperation. However, many of the factors affecting cooperation will be evaluated differently by different actors and in different situations. What is deemed a deal breaker in some cases can be seen as just a minor cost increase in others. Likewise, what is considered a great incentive for joining cooperation by some can be of less interest to others. The gains and the costs of cooperation thus need to be considered case by case and the SAS-090 study therefore provides a decision-support tool, a spreadsheet covering all identified factors. The decision-support tool can help decision-makers single out the projects that are feasible and attractive, from the ones that involve too many hurdles.

The economic theory has been tested in a series of case studies, using real cost data from the study group's participating Nations, on producing a fictive jet fighter aircraft, the NATO Fighter (NF), educating the pilots of the aircraft and operating the aircraft in different scenarios. The case studies show significant savings from cooperating.

In the first case study, investigating cooperation in the acquisition of the NF, the calculations indicate substantial savings from procuring the aircraft in a consortium. In the example of this report, there is a cost reduction of approximately 40 percent between the sole developer scenario and the consortium scenario, after taking into account the increased transaction costs following the cooperation. The potential savings are larger when the fleets to be acquired are smaller.

The second case study looks into cooperation on the education of pilots. The case study investigates two separate scenarios for cooperation: a 3-country cooperation and a 5-country cooperation. As with the case of acquisition, the calculations show significant cost reductions in both cooperation scenarios. Because the

fixed costs of this activity amount to a large share of the total costs, substantial gains result from economies of scale when sharing these costs on more units produced through cooperation. Countries with low pilot throughput initially have the largest economic gains. This indicates that the possible gains from cooperation in this area are increasing as many countries now start to reduce the size of their fleets and thus the number of pilots trained.

The third case study is slightly different from the first two and is based on the assumption that the economic gains from acquiring the same aircraft and educating personnel in cooperation have been utilized. The case study estimates the gains from pooling the aircraft and pilots from several partner Nations for operational use. The gains come from increased availability and flexibility as each Nation can take advantage of its partners' excess capability when needed. The results indicate that the operational benefit that four typical Nations can achieve by aircraft and pilot pooling corresponds to an increase of about 5 – 10 percent in their capacity. In addition to these quantifiable savings, equipment harmonization, reduced logistic footprint and increased resilience will lead to other, non-quantifiable, benefits.

The case studies illustrate the economic and operational savings that can be achieved through defence cooperation – but as the report also shows, there are a number of reasons why cooperation often fails. To gain economic benefits for all partners involved, the cooperation initiative must be organized in ways that take advantage of the potential benefits while at the same time limiting the known costs and disadvantages of cooperation. Each cooperation initiative must be considered on a case-by-case basis, and the decision-support tool presented in the report provides a systematic way of conducting this evaluation. However, this report also presents a list of general recommendations.

In general, Type-S cooperation has a larger potential than Type-I for economic benefits. However, taking into account political and operational considerations, Type-I may in many cases be preferred, as the political and operational disadvantages can be smaller. The relative advantages of Type-I and Type-S cooperation depend on the military level at which the cooperation is taking place. At the highest level, the branch of military services level, the study finds that an absolute level of political and military trust between the collaborating Nations is needed, irrespective of the type of cooperation. At the next level, the capability level, the study finds great potential for closer cooperation. At the capability level one risks that potential political and industrial costs might bring powerful and vocal actors to the table, trying to rally support for their cases. Type-I cooperation might bring out these reactions to a lesser degree, and could therefore be the preferred option here. However, Type-S cooperation should be considered for the low intensity war fighting system or structure elements, where the importance of national sovereignty over the system and the need for tight integration with other parts of the forces are smaller. At the lowest military level, the support level, Type-S cooperation is recommended. We are unlikely to incur significant political or industrial costs here, and the economic benefits from specialization and trade can be substantial. However, if security of supply of the good or service is an absolute demand, Type-I cooperation is recommended.

In order to achieve the benefits from cooperation, partner Nations should focus on areas with a large share of fixed costs such as areas close to critical mass. The organization of cooperation programs should ensure the utilization of Nations' comparative advantages and an increased degree of standardization and commonality should be pursued within the Alliance. Avoiding the large costs and disadvantages requires a close evaluation of the number of partners involved in the collaboration, as the transaction costs tends to increase with the number of Nations. The importance of contracting and strong program management from an early phase is emphasized and clarification of incentives and expectations prior to engagement is stressed. Trade barriers should be minimized and work-share arrangements that are not based on the principle of cost efficiency should be avoided.

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Annex A – AVAILABILITY AND SUSTAINABILITY SIMULATIONS FOR FIGHTER AIRCRAFT: A BRIEF INTRODUCTION TO THE FLYT2 MODEL

A.1 INTRODUCTION

Planning and operating fighter squadrons is a tough challenge with many contributing factors that influence the sortie generation. There is the availability aspect with respect to qualified pilots, ground personnel and mission capable aircraft. In addition there are external factors that can delay or stop the sortie generation for a period of time. Each individual factor is fairly well understood, but when it comes to bringing them together it becomes too complicated to foresee the consequences changes to one factor will have on the overall system. In order to gain a better understanding of this problem a computer simulation model has been developed at the Norwegian Defence Research Establishment (FFI). This has become a useful tool, which has been applied to illustrate the consequences of different levels of ambitions in the Royal Norwegian Air Force (RNoAF).

A.2 THE SIMULATION MODEL

The basic idea for the simulation was to make a representation of each aircraft and move them between the different states they may be in according to the time expectancy in each state. Each aircraft has therefore been categorised as illustrated in Figure A-1, which is a simplified flow diagram for the model. The aircraft can be in either of the following states: fully mission capable indicated as online, airborne, and temporarily not mission capable due to a snag, turnaround, waiting for maintenance or being on maintenance.

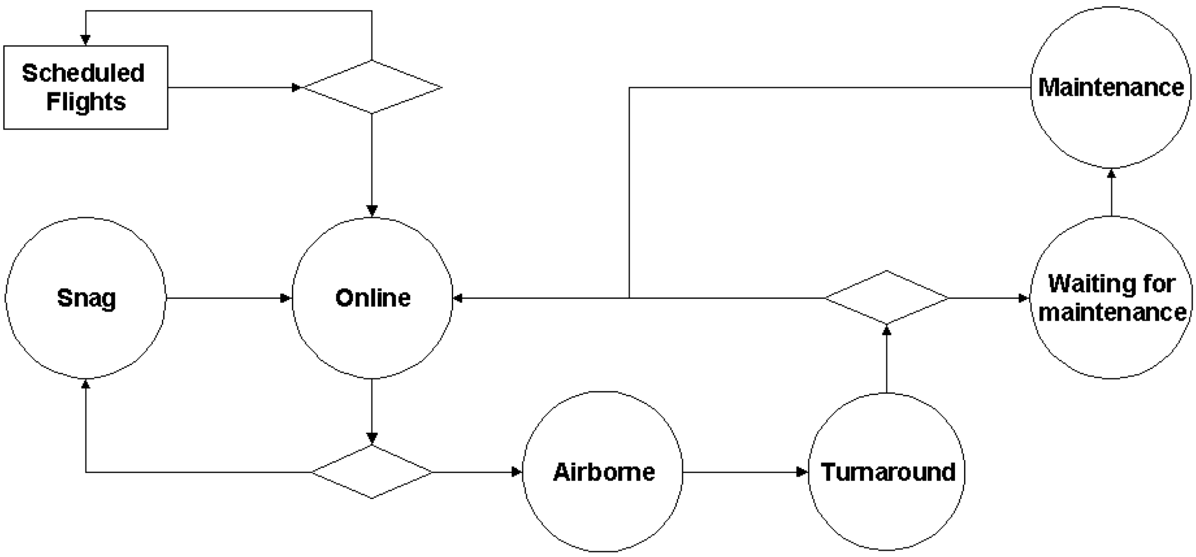

Figure A-1: A Simplified Flow Diagram for the Model.

The scheduling of flights drives the simulation forward. This is an input parameter reflecting the level of intensity of the operation or training for each squadron. At each node indicated with a diamond shaped symbol in the flow diagram, a check is made with a connection corresponding to the event it represents. The first checkpoint represents the ‘go/no go’ due to external factors. The second represents the snag-rate and the third whether the aircraft is due for planned maintenance or not. The maintenance for a fighter aircraft is cyclic according to the number of hours it has flown. There are different levels of maintenance from smaller inspections, which will still take the aircraft out of service for at least a day, to heavy

maintenance such as phase inspection requiring a special dock for the aircraft that may last for several weeks. Normally, a number of aircraft will at any time be out of service due to upgrade programmes such as midlife updates, avionic and structural upgrades, etc.

The short-term maintenance capacity, the number of docks for the phase inspections, and number of non-mission capable aircraft in the fleet due to upgrades are parameters that will influence the results from the simulations. There are some other variables and input parameters such as:

- Number of aircraft;
- Number of squadrons; and
- Pilot-to-aircraft ratio.

The peacetime sortie generation and duration, together with the corresponding numbers for planning for the deployed aircrafts will also have to be set appropriately.

Given all these factors great care must be made to calibrate the model preferably against a good database. The model is a representation of a complex system and it is not always easy to predict the outcome or effect a change to one of the parameters may have on the system. The simplicity of the model allows the testing of different hypotheses by changing some of the input parameters.

In all recent conflicts, air superiority has been achieved quickly and the crucial aspect has been to maintain the operation over a long period of time. When the factors that influence the readiness of an airbase are put together as in this model, one of the observations is that there seems to be a critical size for the air force. What the critical size is will depend on the ambition with regards to the level of commitment at home and in international operations. The airbase as a system must have a balance between maintenance and pilots. The capacity must also meet the requirement with respect to producing a certain number of combat ready aircraft simultaneously to fulfill commitments and to give adequate quality training for the pilots.

A.3 TYPICAL SIMULATION RESULTS WITH THE MODEL

The summary of the results given an aircraft fleet of 50 is included below. In this example, a squadron with 12 aircraft is deployed for three months at six month intervals. The results are presented in Figure A-2 and Figure A-3. Figure A-2 presents flight hours per week against time for an air fleet size of 50 aircraft. The peacetime activity is indicated up to week 50, and in Figure A-2 the weekly average flight hour production is just above 200 hours. During deployment many resources are allocated to meet the planning requirements, resulting in a major reduction in the activity at home. This example also shows that a considerable amount of time is required to recover to a “normal” availability of airplanes (and combat ready pilots). The six months allowed for between the deployments are not adequate to obtain this.

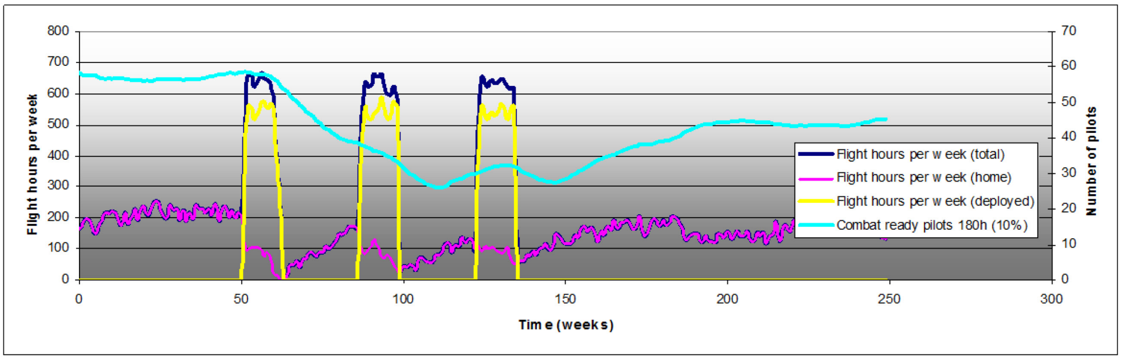

Figure A-2: Flight Hours per Week with 50 Aircraft.

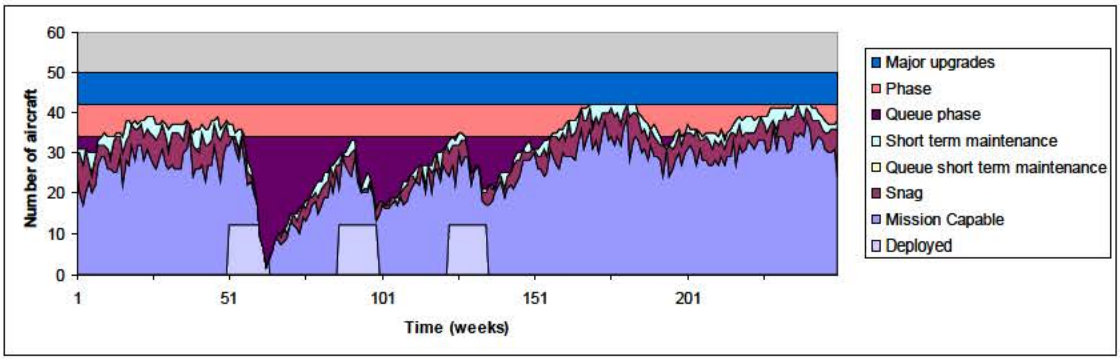

Figure A-3: Availability per Week with 50 Aircraft.

On the secondary axis, the number of combat ready pilots is indicated. To be combat ready, the pilot is required to have at least 180 hours of training the preceding 12 months. Due to the nature of the typical missions flown when deployed, only a part of the flying counts towards the required training programme. In this example only 10 percent of the time is accounted for. A theoretical distribution of the flight hours optimising the number of combat ready pilots is indicated in Figure A-2. As a result of the deployments a considerable reduction in the number of combat ready pilots can be observed.

In Figure A-3 an overview of the number of fighter aircraft in each state is given. The different states are:

- Mission capable;
- Deployed;
- Snag;
- In queue for short-term maintenance;
- On short-term maintenance;
- In queue for phase;
- On phase; or
- On major upgrade.

The colour coding indicates each state. Before the deployment there is a high availability of mission capable aircraft. There is also excess dock capacity. A few weeks into the first deployment period there is a rapid build-up in the phase queue. In fact there are not enough aircraft to sustain the planned activity level throughout the deployment period. This queue takes a long time to process and the airbase will suffer from reduced aircraft availability all the time until the next deployment. Incidentally, the two consecutive deployments do not drain the airbase as badly as the first one due to the reduced activity level imposed by the lack of mission capable aircraft in the periods between the deployments. For an airbase of this size the conclusion is that it will not be possible to sustain the deployment of a squadron given the initial conditions of the system.

A.4 CONCLUSION

The above example demonstrates the use of this model in simulating the impact a deployment will have on the airbase. It may be used to investigate the change in production and readiness on the airbase by changing the conditions for factors such as maintenance, pilot availability, aircraft reliability and aircraft demand.

The results from the example above show that an airbase with only 50 aircraft will not be adequate to sustain a deployment of one squadron if it is to meet the planning number for sortie generation throughout the

deployment. Towards the end of the first deployment period there are no aircraft available to replace the ones due maintenance among those deployed. The flying at home drops to zero and only returns to normal when a new deployment starts. This example also illustrates the consequences if a part of the maintenance system is undersized.

The model is a tool which will help identify the problems that may occur in situations with a high demand for aircraft. As a consequence the necessary precautions may be taken to obtain sustainability of the airbase. The purpose of the model is to test whether or not the proposed changes will have the desired effect.

Annex B – THE CANADIAN STRATEGIC COST MODEL: APPLICATION TO THE ACQUISITION AND LIFE-CYCLE COST ESTIMATION OF THE HYPOTHETICAL NF FIGHTER AIRCRAFT

B.1 THE STRATEGIC COST MODEL

B.1.1 History of Development

The Strategic Cost Model (SCM) began to be developed in 2005 by a cross-departmental working group within the Canadian Department of National Defence (DND) including the Defence Research and Development Canada Centre for Operational Research and Analysis (DRDC CORA). DRDC CORA developed the analytical framework and has since maintained the SCM, updating it as new information was made available. The model provides DND with an integrated view of the cost of military capabilities. In addition to direct costs gathered through a variety of databases maintained within DND, the model relies on attribution rules to estimate the contribution of indirect costs to existing military capabilities. The indirect costs estimated include infrastructure, research and development and training. A portion of all indirect (i.e. supporting) costs is assigned to all entities within DND in charge of delivering operational capabilities. This allows the model to estimate the full cost of each one of these entities.

The cost model is the first attempt to develop 'whole system capability costing' in DND and has been used, among other things, to estimate the cost of the Defence policy statement and other departmental plans. It has also been instrumental in the analysis of the cost implications of options for the replacement of capabilities. The SCM is the main strategic costing tool in support of capability-based planning in Canada.

B.1.2 Model Principles

The SCM consists of future cost estimates for the next 30 years by cost categories including civilian and military personnel, procurement, operations and maintenance, etc. The model also includes attribution tables which describe the rules for attributing supporting costs to different defence programs. Finally the model includes Capability Cost Profiles where each capability (represented by a departmental program) is broken down into its yearly direct costs and indirect costs, for 30 years. All the model information can be aggregated and summarized based on different criteria such as the cost by 'effect' of the cost by operational capability.

The costing is undertaken based on the 'inputs of capabilities' which are represented in DND by the PRICIE construct (Table B-1). These inputs can be estimated with the current DND accounting processes.

Table B-1: The PRICIE Elements.

P	Personnel, leadership and individual training
R	Research and development, operational research
I	Infrastructure and organization
C	Concepts, doctrine and collective training
I	Information technology infrastructure
E	Equipment, supplies and services

B.2 THE NF COST MODEL

B.2.1 Adapting the SCM for the SAS-090 Study

The SCM is a useful tool to estimate life-cycle costs for major equipment fleets. The life-cycle cost of the Canadian fleet of CF-18 fighter aircraft in particular can be extracted from the SCM. The costs of the Canadian CF-18 program were the baseline for the NF cost model used in this study.

The PRICIE components for the F-18 were summarized as shown in Table B-2 to represent a generic fighter aircraft, here the NF.

Table B-2: NF Cost Categories.

<table>
<tr><th></th><th colspan="2">Cost Categories</th></tr>
<tr><td rowspan="8">Direct Costs</td><td rowspan="3">Capital</td><td>Replacement</td></tr>
<tr><td>Betterment</td></tr>
<tr><td>Refit</td></tr>
<tr><td rowspan="3">O&M</td><td>Fuel</td></tr>
<tr><td>National Procurement</td></tr>
<tr><td>Other</td></tr>
<tr><td rowspan="2">Personnel</td><td>Civilian</td></tr>
<tr><td>Military</td></tr>
<tr><td rowspan="8">Indirect Costs</td><td rowspan="4">Infrastructure and Support</td><td>Support Squadrons</td></tr>
<tr><td>Tactical Fighter Base</td></tr>
<tr><td>Air Equipment</td></tr>
<tr><td>Common Equipment</td></tr>
<tr><td>R&D</td><td></td></tr>
<tr><td rowspan="3">Training</td><td>Tactical Air Base Support</td></tr>
<tr><td>Air Training</td></tr>
<tr><td>Common Training</td></tr>
</table>

The cost categories are defined in Table B-3.

Table B-3: NF Cost Categories Definitions.

Direct Costs		
Capital	Replacement	Yearly amortization of the aircraft acquisition costs
	Betterment	Improvements and replacement for weapons, electronics and other on-board systems
	Refit	Schedule refit of the fleet
Operations and Maintenance (O&M)	Fuel	Fuel for the aircraft
	National Procurement	Sustainment costs, i.e. spares and repairs (centrally planned)
	Other	In-service costs for replacement equipment (locally planned)
Personnel	Civilian	Pay and benefits of civilians working directly with the aircraft
	Military	Pay and benefits of fighter pilots and military personnel in charge of first line maintenance
Indirect Costs		
Infrastructure and Support	Support Squadrons	Share of the squadrons' operations budget that can be attributed to the fighter aircraft (including operations and maintenance, civilian pay and military pay)
	Tactical Fighter Base	Tactical fighter bases' operations budget (including housing, communications, health services, etc.)
	Air Equipment	Share of operations, maintenance and personnel costs related to the air force testing and quality assurance facilities and the management of air equipment programs that can be tied to the fighter aircraft
	Common Equipment	Share of operations, maintenance and personnel costs related to the general testing and quality assurance facilities and the management of common equipment programs that can be tied to the fighter aircraft
Research and Development (R&D)		Fraction of the budget of DRDC (including personnel, infrastructure, equipment, etc.) that can be attributed to the fighter aircraft
Training	Tactical Air Base Support	Share of the operations budget of air bases providing fighter training (including operations and maintenance, civilian and military pay)
	Air Training	Share of operations, maintenance and personnel costs of the air training programs and facilities that are related to training for the fighter capability
	Common Training	Share of operations, maintenance and personnel cost of the common training programs and facilities that can be tied to the fighter aircraft

B.2.2 Acquisition Cost Hypothesis

The NF fighter aircraft acquisition cost was determined based on cost-per-ton estimates, derived through projections of historical data ([13]), applied to the weight of the latest generation fighter aircraft. The cost-per-ton estimates provide a lower bound, median and upper bound estimate for the acquisition cost for the NF aircraft. In the case study calculations, the median cost estimate was selected.

In the NF model, the acquisition cost was broken down into two cost categories. The first 96 percent of the acquisition cost was set as the *Capital – Replacement* cost while the remaining 4 percent was assigned to *Capital – Refit*. This was undertaken based on the model of more recent aircraft acquisitions where the cost of the aircraft refit is included in the acquisition price. In the NF model, *Capital – Betterment* costs are based on the CF-18 costs but are linearly adjusted to reflect the new unit acquisition cost. All capital costs in the NF model are yearly averages over a 30-year period, for the entire fleet.

B.2.3 Life-Cycle Costs: Scaling of the SCM for the NF Case Studies

The NF cost model used in the case studies represents the cost of acquiring, maintaining and operating the aircraft for different countries. For this reason, the model is made to be scalable to reflect different possible country features and scenarios. In addition to the fleet size and the unit cost, the NF model may differ from the CF-18 model on the basis of the yearly flying rate, the cost of labour and the yearly student throughput. Cost estimates for the NF model were derived by scaling the F-18 costs based on five factors/rules as set out here[1]:

1) *Operations and maintenance* costs are considered to be directly proportional to the yearly flying rate.

2) *Civilian personnel* costs represent civilian maintainers and so are considered to be directly proportional to the yearly flying rate and to the cost of labor. The *military personnel costs* on the other hand include pilots and first line maintainers and so are proportional to the fleet size and to the cost of labor.

3) The cost of the *basic infrastructure and support* is constant (no change from CF-18) except for the adjustment of salaries for the cost of labor.

4) *Research and development* costs are also constant, i.e. they are not dependent on these scaling factors.

5) *Training* costs are divided between fixed and variable costs. The variable portion is proportional to the student throughput. In the case of salaries, a cost of labor adjustment is also applied. The fixed share of the training costs is 75 percent for the *tactical fighter air base support*, 85 percent for *air training* and 83.5 percent for *common training*.

With these simple rules, it is possible to extend the F-18 cost model to a generic NF cost model which can be scaled to different country sizes and different scenarios. Note that although the model can be scaled to represent very different situations, the accuracy of the estimates will be greater when the features modeled are closer to the Canadian case.

B.2.4 Projection of Life-Cycle Costs

In order to project acquisition and life-cycle costs in the future, the historical rate of 4 percent yearly increase was applied to the capital costs on top of the general economic inflation. Other costs are assumed to change at the same rate as general inflation. The GDP deflator is used to convert current prices into future prices. This model for estimating future costs is very basic and applies only to the 30-year average yearly cost.

[1] A comparative cost of the labour factor was derived based on the International Labour Organization (ILO) Key Indicators of the Labour Market (KILMNET) http://kilm.ilo.org/kilmnet.

Using the SCM, it is possible to project the 'shape' of the yearly cost profiles for each cost category, this can be a starting point to derive a breakdown of the costs over 30 years. However, such a detailed model was not required for the analysis presented in this report.

B.2.5 Limitations of the Model and its Application to the NF Fighter Aircraft

Features of the Canadian CF-18 fleet organization are inherent in the model of the NF despite the scaling. In particular, the ratios of fixed to variable costs assumed for different cost categories are particular to the Canadian context, although the similarity with NATO Allies has been verified. Characteristics such as the size of the country, the number and distribution of the bases and the operational tempo are necessarily implicit to the cost estimates found in the SCM. These considerations have been abstracted out as much as possible through the scaling of the SCM. However, undertaking the same exercise using a different country as a baseline would most likely lead to different results.

Annex C – EXPERIENCES FROM L-159

Table C-1: ALCA L-159 Key Lessons Learned from Cooperation Between Czech Manufacturer (Aero Vodochody) and US Supplier (Boeing).

	Lessons Identified	Lessons Learned
Military Operational	Manufacturer proceeded to design the aircraft as multi-functional for both combat missions (air-to-air, air-to-ground and reconnaissance missions) and training purposes (advanced operational fighter training) due to lack of clear specifications of operational needs.	There is a need to provide a close interaction between all subject military and industry entities participating in developing and designing the aircraft. Military part is to provide (based upon appropriate mechanism for measuring effectiveness of military outputs) clear and bright indications as for priorities in using an aircraft what could be a basis for further analysis of how many aircraft are needed from national perspective.
Military Operational	Technical specifications delivered by the user (Czech Air Force) were not based on conclusions stemming from comprehensive military capability analysis reflecting operational requirements and shortfalls to be covered or mitigated.	
Military Operational	There was no pragmatic specification identifying the number of aircraft needed for the Czech Air Force to keep up with required level of military ambition.	
Economic Marketing	Marketing survey was not able to reveal the real inquiry rate on the international market for the aircraft of that category. An opportunity to trade L-159 on the international defence market is quiet limited due to relatively dense competition.	Defence equipment marketing should present a clear picture of which technology, equipment and material is available throughout international defence markets and analyse potential inquiry rate for an aircraft of given category.
Economic Marketing	The aircraft, as primarily designed, appeared significantly expensive, if a potential user has intention to use it just for training purposes. Due to changing physiognomy of current military operations, L-159 is now more supposed to be used only as a training aircraft for jet supersonic pilot training programmes.	There is a need to have a comprehensive concept covering among others, issues linked to predictions of middle-term and long-term capability requirements.

	Lessons Identified	Lessons Learned
Technological Industrial	Despite the large scale of aircraft meeting given specifications available on the international defence market, it was decided to launch development, production and delivery of the aircraft for the Czech Air Force. The reason was to protect the national air defence industry and to give national industry an opportunity to enhance competitiveness by keeping a high level technological base.	Elaboration of lessons learnt underway.
Political	Due to avionics delivered by the US company Boeing meeting high-tech defence standards, there is the need to ask the US government for authorisation every time the aircraft might become a subject of foreign sale.	All conditions in the contract specifying the position of participating entities were not treated enough. Specifically, the international cooperation treaty dealing with defence equipment should include clauses setting trade conditions with third countries.
Social	Despite the large scale of aircraft on the international market meeting given specifications, it was decided to launch the development, production and delivery of the aircraft for the Czech Air Force. The reason was to maintain the employment rate in the region and to prevent in this manner negative social impacts.	Lessons learnt not available.
Political	Insufficient intergovernmental and interagency cooperation (ministry of defence, ministry of foreign affairs, ministries of industry and defence industry associations) was set up during the whole process of project development, production and introduction of the aircraft into the armed forces.	Lessons learnt not available. Lessons learnt on this issue should arise from broader politico-military consultations.
Economic Marketing	Insufficient intergovernmental and interagency cooperation (ministries of defence, ministries of foreign affairs, ministries of industry and defence industry associations) was set up in providing a visibility of product and during the presentations of the aircraft for international markets.	Lessons learnt not available.

Annex D – SAS-090 DECISION-SUPPORT TOOL

Cooperation initiative:	SAS-090									
Factors	Economical			Political & industrial			Operational			Comments
	Pro	*Con*	*N/A*	*Pro*	*Con*	*N/A*	*Pro*	*Con*	*N/A*	
Economical:										
1. Large scale production has an advantage over small scale production (Economies of scale)										
2. Utilization of common resources by gathering two or more activities (Economies of scope)										
3. Co-production leads to effciency and learning improvements, thus reducing the unit costs (learning curves)										
4. Opportunistic behvaior										
5. Protection of national industry										
6. Enforcement of national standards										
7. Transport costs										
8. Monopoly power										
9. Administration, negotiation & contract costs										
Other considerations:										
10. Technological transfer and knowledge spillover(eg. Sharing sensitive technology & information										
11. Local community consequences (e.g. civilian employment)										
12. Language barriers										
13. Culture barriers										
14. Geographical proximity										
15. Image building in other areas (international relations)										
16. Alliance building										
17. Generating dependices										
18. Relationship to third party nation										
19. Interoperatbility on operational and strategic level										
20. Transfer of military knowledge through training & operational experiences										
21. Gain insight in how to reform the armed forces										
22. Standardizing & harmonizing of equipment										
23. Compromising on operational requirements										
24. Altered operational availability										
26. # of weapon & systems an enemy has to defend against (system spectrum)										
27. Loss of national military expertise										
28. Potential for affecting trust										
29. Reducing logistic footprint										
30. Security of supply										

Figure D-1: SAS-090 Decision-Support Tool.

Annex E – NATO DEFENCE PLANNING PROCESS

E.1 INTRODUCTION

Defence planning in the Alliance is an essential instrument which enables the development and delivery of the necessary forces and capabilities needed to achieve the Organization's objectives. One of the key attributions of the NATO Defence Planning Process is to prevent the re-nationalisation of defence policies and to enhance the international cooperation between NATO Nations.

The aim of the NATO Defence Planning Process is to provide a framework within which national and Alliance defence planning activities are harmonized and synchronised to meet agreed targets in the most effective way. It aims to facilitate the timely identification, development and delivery of the necessary range of capabilities that should be interoperable and adequately tailored in order to allow NATO to conduct a full spectrum of missions.

Defence planning encompasses several planning domains such as:

- Force;
- Resource;
- Armaments;
- Logistics;
- Nuclear;
- C3 (Consultation, Command and Control);
- Civil emergency planning;
- Air defence;
- Air traffic management;
- Standardization;
- Intelligence;
- Medical support; and
- Research and technology.

E.2 STEPS OF THE NATO DEFENCE PLANNING PROCESS

E.2.1 Political Guidance

The NATO Defence Planning Process consists of five steps having basically sequential and cyclical nature. It starts by establishing political guidance reflecting all political, military, economic, legal, civil and technological factors which could impact on the development of the required military capabilities. Furthermore, it clearly defines associated priorities and timelines to be kept in order to fulfill NATO's given Level of Ambition. Political guidance is reviewed at least every four years.

The next step in the NATO Defence Planning Process is preparation of a single consolidated list of minimum capability requirements. These requirements are considered as necessary to meet quantitative and qualitative ambitions set out in the political guidance. The process is structured, comprehensive, transparent and traceable and uses analytical supporting tools coupled with relevant NATO expert analysis.

E.2.2 Identification of Capability Requirements

The next step is apportionment of identified requirements and setting of targets. Target setting initially apportions the overall set of minimum capability requirements to individual NATO Nations and NATO entities in the form of target packages, respecting the principles of fair burden-sharing and reasonable challenge.

The objective is to develop targets for existing and planned capabilities against the minimum capability requirements and cover them in the draft target packages, together with their associated priorities and timelines.

E.2.3 Apportionment of Requirements and Setting of Targets

During the apportionment process, each individual Nation has the opportunity to seek clarification on the content of targets and present its national views on their acceptance.

Subsequently, NATO authorities will consider the NATO Nation's perspective and priorities with the aim of refining the NATO target packages. Based on interactive dialogue between NATO authorities and Nations, refined and individually tailored draft target packages are created to be forwarded to respective NATO Nations.

E.2.4 Implementation of Targets

The following step consists of organising and providing national, multinational or collective efforts whose objective is to satisfy agreed targets and priorities in a coherent and timely manner. The aim is to focus on addressing the most important capability shortfalls. This is achieved by encouraging national implementation, facilitating and supporting multi-national cooperation and proceeding with the collective acquisition of the capabilities required by the Alliance. This step also facilitates national implementation of standardization products (STANAGs / Allied Publications) developed with a view to improve interoperability.

E.3 REVIEW OF RESULTS

Review of results, as a final step, seeks to examine the degree to which NATO's political objectives, ambitions and associated targets have been met and to offer feedback and direction for the next cycle of the defence planning process.

During the capability review process, Allies' defence and financial plans as well as collective efforts are scrutinized and assessed so as to provide an overall assessment of the degree to which achieved capabilities are able to meet the NATO Level of Ambition. Capability reviews will be carried out every two years.

The review process begins with the development of a database on national plans and policies, including Allies' efforts (national, multi-national and collective) to address their planning targets. It also seeks information on the national inventory of military forces and associated capabilities, any relevant non-military capabilities potentially available for Alliance operations and national financial plans.

The database constitutes a basis for conducting a preliminary analysis assessment for each NATO Nation. The summary of these assessments then constitutes a comprehensive analysis of NATO capability state of play as a whole. The summary of assessments is followed by examinations based on which a final report is developed specifying assessment on the military suitability of plans and degree of military risk associated with them. The report will also contain further suggestions and direction to conduct capability development.

Annex F – LESSONS FROM THE EUROMAV CO-PRODUCTION

Figure F-1: Maverick AGM-65 Missile.

In this chapter an example of co-production is analyzed with its benefits and disadvantages. A single example is not sufficient for a general view, but nevertheless, this example has been selected because of its peculiarity: indeed it is the sum of most of the variables to consider in the evaluation of a co-production.

The co-production example refers to the 1985 – 1989 tentative plan for the production in Europe of the Maverick AGM-65 missile. The chapter will describe the setting up of the program management and analyze the causes of the failure of the process.

F.1 CO-PRODUCTION DEFINITION

Co-production of a weapon system or item may involve parallel (duplicative) or interdependent (non-duplicative) production of a weapon system or its components.

Technology transfer from the developing to the non-developing source is an essential issue in the coproduction MOU. A licensing arrangement is typically employed. Coproduction programs are attractive to industry since they involve a clearly defined product and market.

F.2 THE MISSILE

The AGM-65 Maverick is an Air-to-Ground tactical Missile (AGM) designed for close air support. The most widely produced precision-guided weapon in the Western world [4], it is effective against a wide range of tactical targets, including armor, air defences, ships, ground transportation and fuel storage facilities.

Originally designed and built by Hughes Missile Systems, the development of the AGM-65 spanned from 1966 to 1972, after which it entered service with the United States Air Force in August 1972. Since then,

it has been exported to more than 30 countries and is certified on 25 aircraft. The Maverick served during the Vietnam, Yom Kippur, Iran–Iraq and Gulf Wars, and the recent Libya operations, along with other smaller conflicts, destroying enemy forces and installations with varying degrees of success.

Since its introduction into service, numerous Maverick versions have been designed and produced, utilising electro-optical, laser, charge-coupled devices and infra-red guidance systems. The AGM-65 has two types of warheads: one has a contact fuze in the nose, the other has a heavyweight warhead fitted with a delayed-action fuze, which penetrates the target with its kinetic energy before detonating. The Maverick measures more than 2.4 m in length and 30 cm in diameter.

F.3 PRODUCTION

The first production contract was assigned to Hughes in 1971 for 2000 missiles. Between 1975 and 1978 more than 35,000 mavericks were built to be delivered to Central Europe where it was planned to be used against the Warsaw Pact forces.

Since then several other versions of the missile have been developed, the latest being the AGM-65H/K which was in production as of 2007.

F.4 THE EUROPEAN CO-PRODUCTION

In the past, the US has offered a number of systems to the Europeans. In the 1980s six European countries – Denmark, Germany, Italy, Netherlands, Spain, and Turkey – intended to undertake production in Europe, under license, of the Maverick air/ground guided missile equipped with imaging infra-red homing head (IIR).

In November 1984 a memorandum of understanding was concluded between the United States and Italy as lead country for the Maverick AGM-65D for anti-tank action. This was supplemented in July 1986 by an agreement for the versions F (against ship targets) and G (with heavy warhead against fixed targets such as bunkers), equipped with the same homing head.

The total requirement of the European Nations is around 4,000 missiles; a global cost of the programme was evaluated, in 1986, at circa 750 million US dollars.

F.5 SETTING UP OF THE PROGRAM OFFICE

The general contractor for the planned European production is the Selenia-MBB subsidiary EUROMAV, which concluded an agreement with the US developer and producer Hughes on licensing and technical support.

EUROMAV was located in Rome, and was organized with a Program Management Branch, a Technical Branch and an Industrialization Branch. Legal and Commercial support was provided by Selenia and MBB.

The General Contractor referred to a Government Steering Board representing the Nations.

F.6 THE COST/WORK SHARING RULES

The MOU among Denmark, Germany, Italy, Netherlands, Spain, and Turkey listed a few simple sharing rules and constraints, all based on the actual need expressed by each Nation:

- The cost-share should be proportional to the national missile quantities;

- The work-share should be proportional to the national missile quantities;
- Cost-share should include all non-recurring/industrialization costs and production costs, i.e. % acquisition = % cost-share = % work-share;
- The difference between the actual and the target values (percentages) should be as far as possible equal to zero; and
- The final missile production cost should be in line with the US production missile cost (the Nation planned to "absorb" the non-recurring).

F.7 THE PROPOSAL PREPARATION

After intense contact with the US's Hughes Missiles Systems for the definition of the AGM-65D/F/G data pack, the missile was divided into about 80 sub-assemblies and EuroMav prepared an equivalent number of tendering packages.

Each tender received between five and nine proposals (i.e. ca 500 in total).

Unfortunately the "lowest compliant" proposal assembly did not respect the requested rules for work-sharing. The definition of the best combination to respect the three constraints obliged EuroMav to study many different lists of potential suppliers. The process came down to a series of discussions and negotiations among the Nations around the "content and quality" of the work, that was requested also to be reasonably equally distributed.

The above process started in 1985 and continued over the following three years, with some different interim proposals that EuroMav discussed with the Nations Steering Committee.

The consortium proposal was finally delivered in 1988.

F.8 THE EXCHANGE RATE INFLUENCE

The rate of exchange between the US dollar and Denmark, Germany, Italy, Netherlands, Spain, and Turkey changed considerably, with a variation that went from 14 percent to the 100 percent!

This fact caused even more great discussions among the Nations because it was very difficult to follow both the sharing constraints and the change fluctuations.

F.9 THE REASON OF THE FAILURE

The final proposal exceeded the US production unit price by a large percentage even excluding the nonrecurring transfer of technologies and industrialization costs.

The main reasons for this were due to internal and external factors:

- Internal:
  - The rules given by the MoU among the Nations where too strict – the obligation to respect the formula % acquisition = % cost-share = % work-share, obliged to an extreme work for the research of the best combination of suppliers, and a tremendous negotiation among the Nations, the suppliers and the US companies in order to try to minimize risks and costs.
  - The setting up of a very dispersed production sharing within the six participating Nations, in a period when the EU was not yet in existence, and therefore with some difficulties in the inter-team transportation of the produced components.

- External:
  - The proposal preparation and negotiation lasted for several years: the exchange rate between the US dollar and the European currencies changed seriously and contributed to a big increase of the production cost if undertaken in Europe.
  - Between 1987 and 1989 significant political evolution and a radical series of political changes occurred in the Eastern Bloc, associated with the liberalization of the Eastern Bloc's authoritarian systems and the erosion of Soviet political power. This caused a relaxation of the two blocs' tensions and the reduction, at least politically, of the support for new massive production of attack missiles.

F.10 LESSONS LEARNED

From a global point of view, co-production of military systems/equipment is the result of a combination of different factors with different weights and all these factors are used by the different stakeholders – political, operational, and industrial – with different emphases.

The share of technological competencies, the reduction of cost due to a larger production quantity, the lower risk due to different production lines – multiple sources – the political need to link Nations, are some of these.

The European production of the Maverick AGS-65 missile is the example that regroups all of them and demonstrates that considering only one of them as "the most important" is a typical mis-evaluation undertaken by the predominant stakeholder.

In the Maverick example the industrial organization for the production, with a very dispersed set of participating industries belonging to different Nations with very different "working rules", also dispersed responsibilities, and highly centralized risk is another lesson to consider when a new co-production program is evaluated.

REPORT DOCUMENTATION PAGE

1. Recipient's Reference	2. Originator's References	3. Further Reference	4. Security Classification of Document
	STO-TR-SAS-090 AC/323(SAS-090)TP/582	ISBN 978-92-837-0219-1	PUBLIC RELEASE

5. Originator
Science and Technology Organization
North Atlantic Treaty Organization
BP 25, F-92201 Neuilly-sur-Seine Cedex, France

6. Title
Cost Efficiency Implications of International Cooperation

7. Presented at/Sponsored by
Final Report of Task Group SAS-090.

8. Author(s)/Editor(s)	9. Date
Multiple	April 2015

10. Author's/Editor's Address	11. Pages
Multiple	132

12. Distribution Statement
There are no restrictions on the distribution of this document. Information about the availability of this and other STO unclassified publications is given on the back cover.

13. Keywords/Descriptors

Acquisition	Economic gains	Multi-national
Co-development	Economies of scale	Pooling
Co-production	Integration	Role specialization
Cost efficiency	International cooperation	Sharing
Cost growth	Juste retour	Smart defence
Defence spending	Lead nation	Transaction costs
Economic costs		

14. Abstract

This report sets out to evaluate the cost efficiency implications of international military cooperation. Increased cooperation between the NATO Nations is seen as a possible means to reduce the consequences for operational ability of the ever increasing weapon system costs and the stagnating defence budgets. A taxonomy for analyzing cooperation initiatives is proposed based on a categorization of different forms of cooperation initiatives. This taxonomy structures the rest of the analysis.

International cooperation entails both benefits and costs that can be economic, operational or political in nature. The economic benefits are mostly related to economies of scale, resulting from increases in scale when two or more countries combine their efforts. The economic costs are often labeled transaction costs, and will typically increase as the cooperation initiative includes more Nations. The political and operational factors are described in this report mainly as show stoppers or enablers. The trade-offs between cost savings on the one hand and possible political or operational disadvantages on the other hand are not made here, and are instead left for the politicians. A successful cooperation effort is selected and managed in order to maximize these benefits and minimize the costs. The report presents three case studies showing that large economic gains can be achieved through cooperation. The size of the gains that each nation can expect to see in a collaboration initiative depends on the chosen area and design of the collaboration.

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ISBN 978-92-837-0219-1